

# LogMap family results for OAEI 2014 <sup>\*</sup>

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**Abstract.** We present the results obtained in the OAEI 2014 campaign by our ontology matching system LogMap and its variants: LogMap-C, LogMap-Bio and LogMapLt. The LogMap project started in January 2011 with the objective of developing a scalable and logic-based ontology matching system. This is our fifth participation in the OAEI and the experience has so far been very positive.

## 1 Presentation of the system

Ontology matching systems typically rely on lexical and structural heuristics and the integration of the input ontologies and the mappings may lead to many undesired logical consequences. In [13] three principles were proposed to minimize the number of potentially unintended consequences, namely: *(i) consistency principle*, the mappings should not lead to unsatisfiable classes in the integrated ontology; *(ii) locality principle*, the mappings should link entities that have similar *neighbourhoods*; *(iii) conservativity principle*, the mappings should not introduce alterations in the classification of the input ontologies. Violations to these principles may hinder the usefulness of ontology mappings. The practical effect of these violations, however, is clearly evident when ontology alignments are involved in complex tasks such as query answering [17].

LogMap [12, 14] is a highly scalable ontology matching system that implements the consistency and locality principles. LogMap also supports (real-time) user interaction during the matching process, which is essential for use cases requiring very accurate mappings. LogMap is one of the few ontology matching system that *(i)* can efficiently match semantically rich ontologies containing tens (and even hundreds) of thousands of classes, *(ii)* incorporates sophisticated reasoning and repair techniques to minimise the number of logical inconsistencies, and *(iii)* provides support for user intervention during the matching process.

LogMap relies on the following elements, which are keys to its favourable scalability behaviour (see [12, 14] for details).

*Lexical indexation.* An inverted index is used to store the lexical information contained in the input ontologies. This index is the key to efficiently computing an initial set of mappings of manageable size. Similar indexes have been successfully used in information retrieval and search engine technologies [2].

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*Logic-based module extraction.* The practical feasibility of unsatisfiability detection and repair critically depends on the size of the input ontologies. To reduce the size of the problem, we exploit ontology modularisation techniques. Ontology modules with well-understood semantic properties can be efficiently computed and are typically much smaller than the input ontology (e.g. [6]).

*Propositional Horn reasoning.* The relevant modules in the input ontologies together with (a subset of) the candidate mappings are encoded in LogMap using a Horn propositional representation. Furthermore, LogMap implements the classic Dowling-Gallier algorithm for propositional Horn satisfiability [7]. Such encoding, although incomplete, allows LogMap to detect unsatisfiable classes soundly and efficiently.

*Axiom tracking and greedy repair.* LogMap extends Dowling-Gallier’s algorithm to track all mappings that may be involved in the unsatisfiability of a class. This extension is key to implementing a highly scalable repair algorithm.

*Semantic indexation.* The Horn propositional representation of the ontology modules and the mappings are efficiently indexed using an interval labelling schema [1] — an optimised data structure for storing directed acyclic graphs (DAGs) that significantly reduces the cost of answering taxonomic queries [5, 19]. In particular, this semantic index allows us to answer many entailment queries over the input ontologies and the mappings computed thus far as an index lookup operation, and hence without the need for reasoning. The semantic index complements the use of the propositional encoding to detect and repair unsatisfiable classes.

## 1.1 Adaptations made for the 2014 evaluation

In the OAEI 2014 campaign we have participated with 3 additional variants:

**LogMapLt** is a “lightweight” variant of LogMap, which essentially only applies (efficient) string matching techniques.

**LogMap-C** is a variant of LogMap which, in addition to the consistency and locality principles, also implements the conservativity principle (see details in [21, 20]). The repair algorithm is more aggressive than in LogMap, thus we expect highly precise mappings but with a significant decrease in recall.

**LogMap-Bio** includes an extension to use BioPortal [10, 11] as a (dynamic) provider of mediating ontologies instead of relying on a few preselected ontologies [4]. In the OAEI 2014, LogMap-Bio uses the top-5 mediating ontologies given by the algorithm presented in [4]. Note that, LogMap-Bio only participates in the biomedical tracks. In the other tracks the results are expected to be the same as LogMap.

LogMap’s algorithm described in [12, 14] has also been adapted with the following new functionalities:

*i* **Multilingual support.** We have implemented a multilingual module based on *google translate*<sup>4</sup> to participate in the Multifarm track. Additionally, in order to split Chi-

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<sup>4</sup> Currently we use the (unofficial) API available at <https://code.google.com/p/google-api-translate-java/>.

nese words, we rely on the ICTCLAS library<sup>5</sup> developed by the Institute of Computing Technology of the Chinese Academy of Sciences.

- ii **Extended repair algorithm.** We have extended the Horn propositional projection of the input ontologies to involve data and object properties in the repair process [24]. LogMap's repair module is now more complete and it is also able to repair (object and data) property mappings.<sup>6</sup>
- iii **Extended interactive support.** The interactive algorithm described in [14] has been slightly extended to include object and data properties in the process. Note that this extension was already included in the OAEI 2013 campaign.

## 1.2 Link to the system and parameters file

LogMap is open-source and released under GNU Lesser General Public License 3.0.<sup>7</sup> Latest components and source code are available from the LogMap's Google code page: <http://code.google.com/p/logmap-matcher/>.

LogMap distributions can be easily customized through a configuration file containing the matching parameters.

LogMap, including support for interactive ontology matching, can also be used directly through an AJAX-based Web interface: <http://csu6325.cs.ox.ac.uk/>. This interface has been very well received by the community, with more than 1,500 requests processed so far coming from a broad range of users.

## 1.3 Modular support for mapping repair

Only very few systems participating in the OAEI competition implement repair techniques. As a result, existing matching systems (even those that typically achieve very high precision scores) compute mappings that lead in many cases to a large number of unsatisfiable classes.

We believe that these systems could significantly improve their output if they were to implement repair techniques similar to those available in LogMap. Therefore, with the goal of providing a useful service to the community, we have made LogMap's ontology repair module (LogMap-Repair) available as a self-contained software component that can be seamlessly integrated in most existing ontology matching systems [15, 9].

## 2 Results

In this section, we present a summary of the results obtained by the LogMap family in the OAEI 2014 campaign. Please refer to <http://oaei.ontologymatching.org/2014/results/index.html> for complete results.

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<sup>5</sup> <https://code.google.com/p/ictclas4j/>

<sup>6</sup> The OAEI 2014 coherence results does not exhibit these improvements since only the conference track ontologies involve mappings among properties and LogMap 2013 was already coherent. It does have, however, an impact when repairing other mapping sets as shown in [24].

<sup>7</sup> <http://www.gnu.org/licenses/>

Table 1: Results for Benchmark track.

System	biblio			cose			dog		
	P	F	R	P	F	R	P	F	R
LogMap	0.40	0.40	0.40	0.38	0.41	0.45	0.96	0.15	0.08
LogMap-C	0.42	0.41	0.40	0.39	0.41	0.43	0.98	0.15	0.08
LogMapLt	0.43	0.46	0.50	0.37	0.43	0.50	0.86	0.71	0.61

Table 2: Results for Anatomy track.

System	P	F	R	Time (s)
LogMap-Bio	0.888	0.897	0.906	535
LogMap	0.918	0.881	0.846	12
LogMap-C	0.975	0.802	0.682	22
LogMapLt	0.962	0.829	0.728	5

## 2.1 Benchmark track

Ontologies in this track have been synthetically generated. The goal of this track is to evaluate the matching systems in scenarios where the input ontologies lack important information (e.g., classes contain no meaningful URIs or labels) [8].

Table 1 summarises the average results obtained by LogMap and its variants. Note that the computation of candidate mappings in LogMap (and its variants) heavily relies on the similarities between the vocabularies of the input ontologies; hence, there is a direct negative impact in the cases where the labels are replaced by random strings. Surprisingly, LogMapLt obtained the best results in the dog test case.

## 2.2 Anatomy track

This track involves the matching of the Adult Mouse Anatomy ontology (2,744 classes) and a fragment of the NCI ontology describing human anatomy (3,304 classes). The reference alignment has been manually curated [25], and it contains a significant number of non-trivial mappings.

Table 2 summarises the results obtained by the LogMap family. LogMap-Bio ranked 2nd in the track. The use of BioPortal as mediating ontology provider had a significant improvement in recall. LogMap-Bio runtime is near 10 minutes since the discovery of the mediating ontologies is performed on-the-fly [4]. Regarding mapping coherence, only two tools (apart from LogMap, LogMap-C and LogMap-Bio) generated coherent alignments. The evaluation was run on a server with 3.46 GHz (6 cores) and 8GB RAM.

## 2.3 Conference track

The Conference track uses a collection of 16 ontologies from the domain of academic conferences [23]. These ontologies have been created manually by different people and

Table 3: Results for Conference track.

System	RA1 reference			RA2 reference		
	P	F	R	P	F	R
LogMap	0.80	0.68	0.59	0.76	0.63	0.54
LogMap-C	0.82	0.67	0.57	0.78	0.62	0.52
LogMapLt	0.73	0.59	0.50	0.68	0.54	0.45

Table 4: Results for Multifarm track.

System	Different ontologies			Same ontologies		
	P	F	R	P	F	R
LogMap	0.80	0.40	0.28	0.94	0.41	0.27

are of very small size (between 14 and 140 entities). The track uses two reference alignments RA1 and RA2. RA1 contains manually curated mappings between 21 ontology pairs, while RA2 also contains composed mappings based on the alignments in RA1.

Table 3 summarises the average results obtained by the LogMap family. The last column represents the total runtime on generating all 21 alignments. Tests were run on a laptop with Intel Core i5 2.67GHz and 8GB RAM. LogMap ranked 2nd and LogMap-C ranked 3rd. They both produced coherent alignments.

## 2.4 Multifarm track

This track is based on the translation of the OntoFarm collection of ontologies into 9 different languages [18].

In the OAEI 2014, only LogMap, AML and XMap implemented specific multilingual techniques. Table 4 summarises the results. LogMap achieved very competitive results in terms of precision. Regarding recall, however, there is still room for improvement. In the close future we plan to extend the multilingual module with more sophisticated translation techniques.

## 2.5 Library track

The library track involves the matching of the STW thesaurus (6,575 classes) and the TheSoz thesaurus (8,376 classes). Both of these thesauri provide vocabulary for economic and social sciences. Table 5 summarises the results obtained by the LogMap family. The track was run on a computer with one 2.4GHz core with 7GB RAM and 2 cores. LogMap ranked 2nd in this track. The results for LogMap\* are obtained with a version of the input OWL ontologies using skos labels (i.e. *skos:altLabel* and *skos:prefLabel*).

## 2.6 Interactive matching track

The interactive track is based on the conference track and it uses the RA1 reference alignment as Oracle. Table 6 summarizes the obtained results by LogMap with the

Table 5: Results for Library track.

System	P	R	F	Time (s)
LogMap*	0.743	0.711	0.681	223
LogMap	0.775	0.705	0.648	74
LogMapLt	0.644	0.703	0.771	9
LogMap-C	0.484	0.342	0.264	22

Table 6: Results for Interactive track.

System	RA1 reference			Avg. Calls	Time (s)
	P	R	F		
LogMap	0.88	0.73	0.64	4	27

Table 7: Summary results for the Large BioMed track

System	Total Time (s)	P	F	R	Inc. Degree.
LogMap	1,751	0.890	0.792	0.719	0.013%
LogMap-Bio	8,634	0.843	0.784	0.744	0.8%
LogMap-C	6,331	0.907	0.688	0.559	0.013%
LogMapLt	317	0.868	0.613	0.532	34.0%

interactive mode activated. LogMap with interactivity improved both the average Precision and Recall wrt LogMap with the interactive mode deactivated (see Section 2.3). LogMap performed on average, 3.91 calls to the Oracle along the 21 matching tasks. LogMap ranked 2nd in the interactive matching track, but it was the system performing less calls to the oracle.

## 2.7 Large BioMed track

This track consists of finding alignments between the Foundational Model of Anatomy (FMA), SNOMED CT, and the National Cancer Institute Thesaurus (NCI). These ontologies are semantically rich and contain tens of thousands of classes. UMLS Metathesaurus [3] has been selected as the basis for the track reference alignments.

Table 7 summarises the results obtained by the LogMap family. The table shows the total time in seconds to complete all tasks in the track and averages for Precision, Recall, F-measure and Incoherence degree. The track was run on a Ubuntu Laptop with an Intel Core i7-4600U CPU @ 2.10GHz x 4 and allocating 15Gb of RAM..

Only AML and LogMap variants (excluding LogMapLt) generated almost coherent alignments. LogMap ranked 2nd in the track, while LogMap-C and LogMap-Bio obtained the best average Precision and the second best average Recall, respectively. LogMapLt was the fastest to complete all tasks.

Table 8: Results for OA4QA track.

System	Queries	RA1 reference			RAR1 reference		
		P	F	R	P	F	R
LogMap	18/18	0.750	0.741	0.750	0.729	0.728	0.750
LogMapC	18/18	0.722	0.704	0.694	0.722	0.703	0.694
LogMapLt	11/18	0.409	0.379	0.423	0.351	0.348	0.402

Table 9: Results for Instance matching track.

System	Identity		
	P	F	R
LogMap	0.603	0.099	0.054
LogMap-C	0.642	0.078	0.042

## 2.8 OA4QA track

The Ontology Alignment for Query Answering (OA4QA) track [22] does not follow the classical ontology alignment evaluation with respect to a set of reference alignments. Precision and recall is calculated with respect to the ability of the generated alignments to answer a set of queries in a ontology-based data access scenario where several ontologies exist. Given a query and an ontology pair, a model (or reference) answer set is computed using the correspondent reference alignment for the ontology pair. Precision and recall is calculated with respect to these model answer sets.

In the OAEI 2014 the ontologies and reference alignment (RA1) are based on the conference track. RAR1 is a repaired version of RA1 different from RA2 in the conference track. Table 8 summarises the (average) results for the LogMap family. LogMap and LogMap-C ranked 1st and 2nd in the track, although the number of queries is still not large enough to provide representative values for Precision and Recall. However, the most interesting result is the number of queries a system is able to answer when the computed alignments is incoherent. For example, LogMapLt, since it does not implement mapping repair techniques, is only able to answer 11 of the queries, which damages the obtained precision and recall.

## 2.9 Instance matching track

The results of LogMap (and LogMap-C) were not as good as previous years. Note that, LogMap does not implement specialised instance matching techniques. Nevertheless, LogMap outperformed two of the participating tools specialised in instance matching. Table 9 summarises the results obtained by LogMap and LogMap-C.

# 3 General comments and conclusions

## 3.1 Comments on the results

LogMap, apart from Benchmark and Instance Matching tracks for which does not implement specific techniques, has been one of the top systems in the OAEI 2014. Fur-

thermore, it has also been one of the few systems implementing repair techniques and providing (almost) coherent mappings in all tracks.

LogMap's main weakness relies on the fact that the computation of candidate mappings is based on the similarities between the vocabularies of the input ontologies; hence, there is a direct negative impact in the cases where the ontologies are lexically disparate or do not provide enough lexical information (e.g. Benchmark and Instance Matching).

### 3.2 Discussions on the way to improve the proposed system

LogMap is now a stable and mature system that has been made available to the community. There are, however, many exciting possibilities for future work. For example we aim at improving the multilingual features and the current use of external resources like BioPortal. Furthermore, we are applying LogMap in practice in the domain of oil and gas industry within the FP7 Optique<sup>8</sup> [16], which presents a very challenging scenario.

### 3.3 Comments on the OAEI test cases

The number and quality of the OAEI tracks is growing year by year. However, there is always room for improvement:

*Comments on the OA4QA track.* The new OA4QA track has successfully shown the negative impact of a incoherent alignment in query answering tasks. However, the number of queries is still small to provide representative values for the F-measure. More queries and more challenging ontologies will make the track more attractive.

*Comments on the OAEI interactive matching track.* The interactive track has been a very important step forward in the OAEI, however, larger and more challenging tasks should be included. For example, matching tasks (e.g. anatomy and largebio) where the number of questions to the expert user or Oracle may be critical. Furthermore, it is quite unlikely that the expert user will be perfect, thus, the interactive matching track should also consider the evaluation of several Oracles with different error rates such as the evaluation performed in [14].

*Comments on the OAEI largebio track.* One of the objectives of the largebio track is the creation of a "silver standard" reference alignment by harmonising the output of the different participating systems. In the next OAEI campaign it would be very interesting to actively use this "silver standard" in the construction of the track's reference alignment. This will help to improve the completeness of the reference alignment.

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<sup>8</sup> <http://www.optique-project.eu/>



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