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Ontology matching: A literature review

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ABSTRACT

The amount of research papers published nowadays related to ontology matching is remarkable and we believe that reflects the growing interest of the research community. However, for new practitioners that approach the field, this amount of information might seem overwhelming. Therefore, the purpose of this work is to help in guiding new practitioners get a general idea on the state of the field and to determine possible research lines.

To do so, we first perform a literature review of the field in the last decade by means of an online search. The articles retrieved are sorted using a classification framework that we propose, and the different categories are revised and analyzed. The information in this review is extended and supported by the results obtained by a survey that we have designed and conducted among the practitioners.

1. Introduction

Ontology matching is a complex process that helps in reducing the semantic gap between different overlapping representations of the same domain. The existence of such different representations obeys to the natural human instinct to have different perspectives and hence to model problems differently. When these domains are represented using ontologies, the solution typically involves the use of ontology matching techniques.

Ontologies and ontology matching techniques are an increasing trend as ontologies provide probably the most interesting opportunity to encode meaning of information. The last decades have born witness to a period of extensive research in this field. Nowadays, far from dying down, the activity seems to be increasing and new publications, where the ontology matching field is addressed, are continuously being released.

This reflects the global interest in ontology matching which we have studied by means of an analytical review of the literature so far. Other works and publications have successfully presented the state-of-the-art in the field such as, Euzenat (2004), Shvaiko and Euzenat (2013) and Kalfoglou and Schorlemmer (2003b), although our purpose is quite different. We aim at retrieving articles related to ontology matching that have been published in the last decade, to classify and identify research lines relevant for ontology matching. We also aim at providing a reference framework for the integration and classification of such articles. Therefore practitioners approaching the field for the first time would be aware of the different types of publications regarding the field to better choose those that better fits their needs, they would gain knowledge about the main issues where the researchers have been working and what are the main trends and challenges still to be addressed in the next years.

To this end, the remainder of the paper is organized as follows. In Section 2 a methodology to extract the articles is presented. Section 3 presents general statistical results of the retrieved publications. Then, Section 4 illustrates the classification framework proposed and describes each one of the categories defined. In Section 5 we describe the limitations of the literature review and suggest a practitioner-oriented survey to support the results of the review. Such review is detailed in Section 6, and its limitations in Section 7. Finally, in Section 8 we present our discussion, concluding remarks and directions for future work.

2. Procedures

To retrieve the articles for this literature review, several well-known online databases were queried to obtain articles related to the ontology matching field. As result over 1600 articles were obtained which were filtered to narrow down the selection to the final 694 articles that are included in this review. This screening allowed dismissing 58.09% of the initially retrieved articles. Although this is a high percentage of the articles it is worth noticing that the original search was broadly defined so an important number of false positives among the initial results were already expected. The screening of the articles was manually done, and

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took over 3 months to complete it due to the several iterations and the amount of articles reviewed.

This review covers journal articles and conference proceedings published within the last decade. Other publication forms such as books, newspapers, doctoral dissertations, posters, etc., were not considered as researchers use mainly journals and conference papers to obtain and spread knowledge, thus these types of publications encompass the majority of the research papers published about this subject.

The procedure followed to identify and filter the papers is reflected in Fig. 1. First, different online databases were queried using a combination of the following search strings: *ontology matching*, *ontology mapping* and *ontology alignment*. These databases were: *IEEEXplore Digital Library* (IEEXplore, 2013), *Science Direct* (Direct, 2013), *ACM Digital Library* (ACM, 2013) and *Scopus* (Scopus, 2013).

In addition to these databases, the articles published in the *Ontology Alignment Evaluation Initiative (OAEI)* (OAEI, 2013) were also included as this initiative is considered as the most prominent one regarding the evaluation of different matching systems and it helps practitioners improve their works on matching techniques.

Sorting these data sources by amount of articles we have: Scopus (626), ACM Digital Library (383), Science Direct (267), OAEI (254) and IEEEXplore Digital Library (126), making this way a total of 1656 articles initially obtained.

The next step was to dismiss those articles that were duplicated, i.e, that have been obtained through two or more data sources. When this situation arose, the criterion followed was to dismiss the articles belonging to the data source with a higher number of articles. By doing so, 335 articles were removed.

Next, the 1321 remaining articles were analyzed considering their keywords and abstracts. Those whose keywords did not include specific mentions to the ontology matching field or whose abstracts did not introduce a research regarding this field were excluded. Of all the criteria considered, this was the one that produced the sharpest cut down in the amount of articles. Additionally, while reviewing the keywords and abstracts, also the papers that corresponded to a poster publication were dismissed.

Finally, the 795 articles remaining were carefully reviewed to dismiss those that did not consider ontology matching as their core part. By applying this criterion another 101 articles were excluded, therefore leaving the 694 articles that are included in this literature review.

3. Statistical results

In this section some statistical information about the articles is presented and discussed. Articles were analyzed regarding publication year and database from which they were obtained.

3.1. Articles sorted by publication year

Fig. 2 represents the progression of the number of articles with respect to their publication years. The measurements and values that shape this progression are shown in Table 1. In this figure we can observe that the amount of published articles steadily increases from 2003 to 2012, where it peaks. The sharpest rise was found between 2005 and 2006 where the percentage of published articles rose from 3.75% to 8.36%. Between 2012 and 2013 we observe a pronounced decrease in the amount of published articles, although as this review covers only the first semester of 2013, it is highly likely that the amount of published articles by the end of the year would follow the increasing trend of the previous years. This increasing pattern reflects the global interest of the research community in the ontology matching field.

3.2. Articles sorted by data source

To retrieve the articles for this literature review, a total of five different data sources were used. Among these, four are well-known online databases that were queried to obtain the articles. The other source was the Ontology Alignment Evaluation Initiative site, where all the publications related to this initiative are published.

The classification of the retrieved articles by data source is shown in Table 2 and graphically depicted in Fig. 3. These data state that Scopus provides the highest amount of articles to the total (41.79%, 290 articles) probably because it includes a wider variety of source journals. On the other hand, ScienceDirect pro-

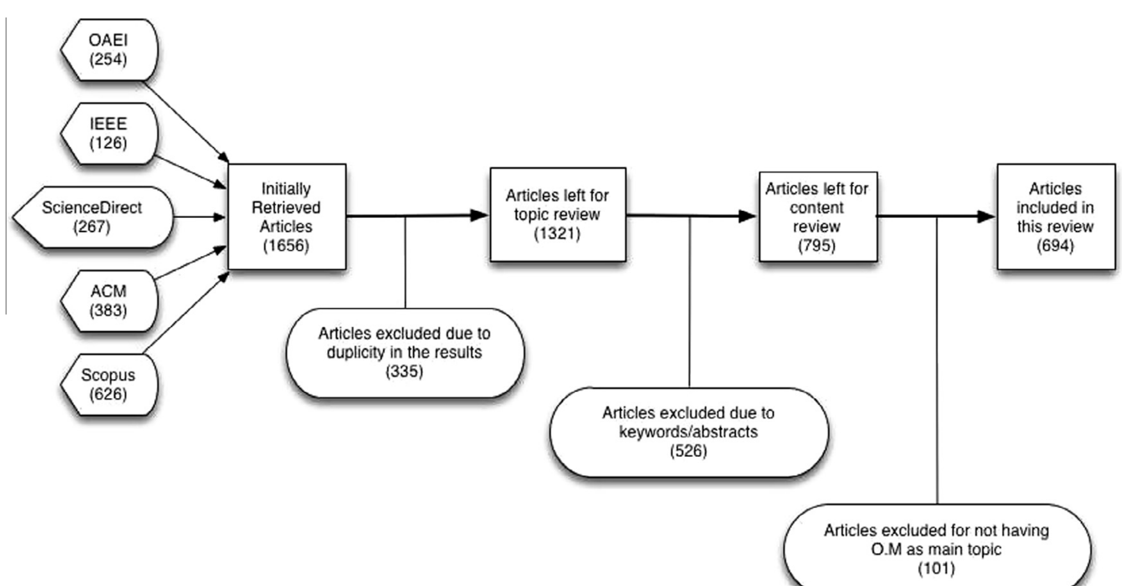

Fig. 1. Procedure followed to retrieve the articles for the literature review.

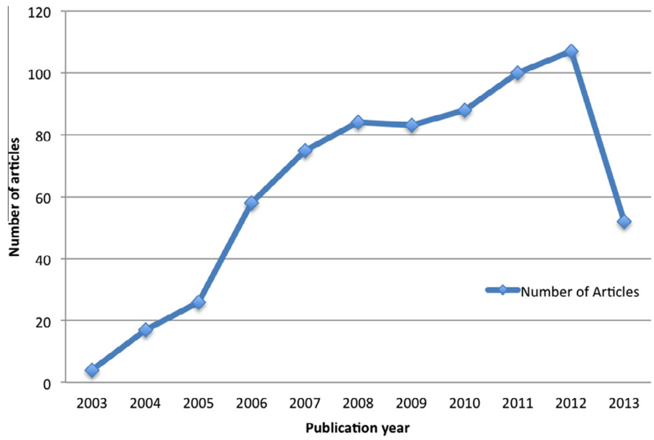

Fig. 2. Articles sorted by publication year.

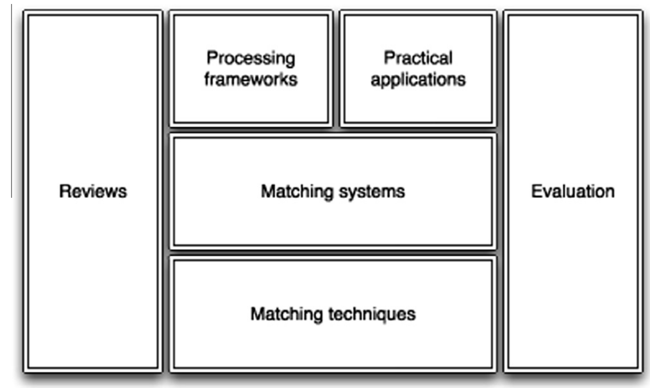

Fig. 4. Classification Framework.

Table 1
Articles with respect to publication year.

Publication year	Number of articles	Percentage over total (%)
2003	4	0.58
2004	17	2.45
2005	26	3.75
2006	58	8.36
2007	75	10.81
2008	84	12.10
2009	83	11.96
2010	88	12.68
2011	100	14.41
2012	107	15.42
2013	52	7.49
Total	694	

Table 2
Articles with respect to data source.

Data source	Number of articles	Percentage over total (%)
ACM Digital Library	72	10.37
IEEExplore Digital Library	114	16.43
Ontology Alignment Evaluation Initiative	174	25.07
ScienceDirect	44	6.34
Scopus	290	41.79
Total	694	

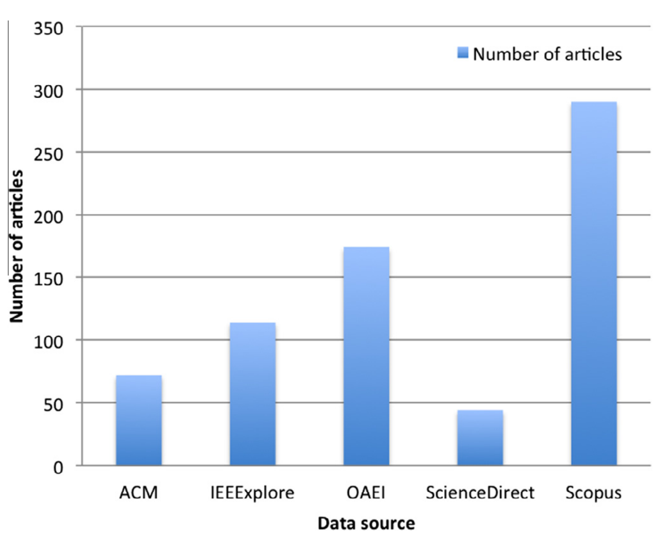

Fig. 3. Articles sorted by data source.

vided significantly less articles than any of the other data sources analyzed (6.34%, 44 articles). The remaining data sources considered respectively provide the 10.37% (72 articles, ACM Digital Library), 16.43% (114, IEEExplore Digital Library) and 25.07% (174 articles, OAEI).

During the first filtering step (see Fig. 1) after initially retrieving the articles from the different data sources, they were processed in order to remove those duplicate results. In this situation the article was always removed from the data source that had more articles as the impact in the overall results for each database would be less significative than in the case of dismissing those from the data sources with less articles.

4. Classification

Relying on the analysis of the articles selected for the literature review, we have defined an abstract framework that helps classifying them. This framework, depicted in Fig. 4, shows six different types of articles and it is in line with the general outline of the main issues in ontology matching proposed by Euzenat and Shvaiko in Euzenat and Shvaiko (2007, 2013). The different categories identified cover the most prominent fields of interest in ontology matching.

- *Reviews.* This category includes the publications devoted to surveying and reviewing the field of ontology matching. It also includes those articles focused on detailing the state-of-the-art as well as the future challenges in this field.
- *Matching techniques.* This category covers the publications focused on different similarity measures, matching strategies and methodologies, that can be used in the matching systems.
- *Matching systems.* This category includes those articles introducing new matching systems and algorithms, and also those detailing enhancements to existing ones.
- *Processing frameworks.* This category comprehends the articles that delve into the different uses of the alignments, i.e, those operations that can be performed from alignments, such as ontology merging, reasoning or mediation.
- *Practical applications.* This category covers those articles that describe matching solutions applied to a real-life problem.
- *Evaluation.* This category covers the articles describing different available approaches to evaluate the matching systems, as well as the different existing benchmarks and the most relevant performance measures.

The results of classifying the articles within the framework defined are summarized in Table 3. According to our results the

Table 3
General results of the classification.

Category	Number of articles	Percentage (%)
Reviews	46	6.63
Matching techniques	85	12.25
Matching systems	302	43.52
Processing frameworks	147	21.18
Practical applications	76	10.95
Evaluation	38	5.48
Total	694	

greater efforts have been focused on developing matching systems and frameworks that exploit the alignments, while the evaluation of such systems as well as the review of the field and the development of applied solutions have not been object of such dedication.

In Table 4 the results of the classification are shown sorted by year, identifying the amount of articles that match into each category and its yearly percentage. These results are graphically compared in Fig. 5 where the evolution can be more clearly distinguished.

The amount of articles into *Reviews* showed an slight but upward trend within the first five years of the time frame considered, peaking in 2008. Ever since, the trend in the amount of reviews per year has remained almost constant. The evolution of the *Matching Techniques* did not show any significant change until 2007 when the amount of articles rose from three to thirteen. After this sharp increase, the values remained constant for the next year and then they fell to six in 2009. In 2010 there was another significant increase, followed by yet another fall in the amount of articles. Apparently the periods of intense work in this category are followed by others where the amount of publications is significantly lower.

Regarding the *Matching Systems*, the amount of published articles shows an upward trend in the considered period, since, as stated before, the values for 2013 can not be considered definitive as the articles for this review were retrieved in the first semester of the year. Regardless of the general upward trend, the amount of articles in this category reached some local peaks in 2006, 2009 and 2012, followed by periods of less activity. Anyway, it is important to notice that the periods of lower activity in this category correspond with periods of higher activity in *matching techniques* and vice versa. It is highly likely that the same researchers that define new matching systems are the ones that had suggested new matching techniques to be used within them, which also validates the process of construction of a matching system.

The evolution in the number of *Processing Frameworks* was increasingly constant until 2007 when it reached a local peak, just to show a slight downward trend for two years, before starting a continuos rise that took the amount of published articles regarding this category to its top value in 2012.

Regarding the *Practical applications*, the amount of articles shows in general an upward trend. It reaches a local peak in 2007 with 8 articles. In 2008 it shows a slight decrease. However, since 2010, the number of articles continues to rise every year. It is worth noticing that even when the data for 2013 does not cover the whole year, the amount of articles devoted to practical applications was already a 66.6% of the articles published in 2012 in the same category.

Finally, the publications related to *Evaluation* show an evolution pattern really similar to the one detected for the *reviews*, not showing any significant behavior.

After providing some general outline of the evolution of the different categories over the years, in the following sections a deeper analysis of each one of them is included, considering inner classifications for each one of these general categories.

4.1. 'Reviews' category

Within this category the publications have been further sorted according to their scope, namely, the publications were identified as being of either *general purpose* or *specific purpose*, as depicted in Fig. 6. More than half of the 46 articles included in this category, 26, were considered *general purpose reviews* as they offer some insight into the ontology matching field without specifically emphasizing on any subject. Among these, there are for instance, *surveys* (Falconer, Noy, & Storey, 2007; Shvaiko & Euzenat, 2005; Thayasivam, Chaudhari, & Doshi, 2012; Zhu, 2012), *state-of-the-art articles* (Droge, 2010; Gal & Shvaiko, 2008; Ngo, Bellahsene, & Todorov, 2013) and publications unveiling the *future challenges* of the field (Kotis & Lanzenberger, 2008; Shvaiko & Euzenat, 2013).

In turn, the remaining 20 articles show a more limited scope within the field. When analyzing these articles we have stated that they were devoted either to delving into a very specific area within the ontology matching field or to studying the feasibility of applying ontology matching to a certain domain.

Some of the specific fields within ontology matching that were addressed cover topics such as (i) *matching across different languages* (Fu, Brennan, & O'Sullivan, 2009), (ii) *instance-based matching* (Castano, Ferrara, Lorusso, & Montanelli, 2008), which is one among the different types of techniques to perform ontology matching. Other articles developed the subject of (iii) *external sources for ontology matching* (Fugazza & Vaccari, 2011; Lin & Sandkuhl, 2008a), these techniques take advantage of auxiliary or external resources in order to find matchings to terms based on linguistic relations between them such as synonymy or hyponymy. These external resources are usually lexicons or thesauri.

On the other hand, among the domains where ontology matching could be used, we have identified articles on domains such as *geography* (Tomaszewski & Holden, 2012), *medicine* (Wennerberg, 2009) or *agriculture* (Lauser et al., 2008).

4.2. 'Matching Techniques' category

Ontology matching techniques propose different approaches for the matching that are implemented in ontology matching algorithms. When building an ontology matching system, different algorithms are usually used, exploiting therefore different ontology matching techniques. In this category two different types of articles have been identified. Some articles are devoted to describing new or enhanced *similarity measures* and to analyzing the *building blocks* of the ontology matching algorithms, while others make use of such artifacts to define *matching strategies* or *methodologies*.

In total there are 85 articles in this category, where 57.65% (49 articles) belong to the first group of *basic matching techniques* and 42.35% (36 articles) belong to *complex matching techniques*.

The different matching techniques have been subject of study in the latest years. For the purpose of this review, to sort the (i) *basic matching techniques* we have followed the classification proposed by Euzenat and Shvaiko (Euzenat & Shvaiko, 2013), depicted in Fig. 7, since to the best our knowledge is the most complete one and reflects most of the other previous classifications. This classification is an evolution of another previously proposed by the same authors in Euzenat and Shvaiko (2007).

This classification can be followed top-down and therefore focusing on the interpretation that the different techniques offer to the input information, but also bottom-up, focusing on the type of the input that the matching techniques use. Despite the followed approach both meet at the *concrete techniques* tier.

Following the top-down interpretation, the matching techniques can be classified in a first level as:

Table 4
Results of the classification.

Year	Category	Number of articles	Total	Annual percentage
2003	Reviews	1	4	25.00%
	Matching techniques	–		–
	Matching systems	1		25.00%
	Processing frameworks	2		50.00%
	Practical applications	–		–
	Evaluation	0		–
2004	Reviews	1	17	5.88%
	Matching techniques	5		29.41%
	Matching systems	6		35.29%
	Processing frameworks	3		17.65%
	Practical applications	–		–
	Evaluation	2		11.76%
2005	Reviews	4	26	15.38%
	Matching techniques	3		11.54%
	Matching systems	6		23.08%
	Processing frameworks	9		34.62%
	Practical applications	1		3.85%
	Evaluation	3		11.54%
2006	Reviews	2	58	3.45%
	Matching techniques	3		5.17%
	Matching systems	30		51.72%
	Processing frameworks	18		31.03%
	Practical applications	4		6.90%
	Evaluation	1		1.72%
2007	Reviews	4	75	5.33%
	Matching techniques	13		17.33%
	Matching systems	27		36.00%
	Processing frameworks	19		25.33%
	Practical applications	8		10.67%
	Evaluation	4		5.33%
2008	Reviews	8	84	9.52%
	Matching techniques	13		15.48%
	Matching systems	34		40.48%
	Processing frameworks	16		19.05%
	Practical applications	5		5.95%
	Evaluation	8		9.52%
2009	Reviews	5	83	6.02%
	Matching techniques	6		7.23%
	Matching systems	46		55.42%
	Processing frameworks	11		13.25%
	Practical applications	10		12.05%
	Evaluation	5		6.02%
2010	Reviews	3	88	3.41%
	Matching techniques	18		20.45%
	Matching systems	37		42.05%
	Processing frameworks	16		18.18%
	Practical applications	10		11.36%
	Evaluation	4		4.55%
2011	Reviews	4	100	4.00%
	Matching techniques	9		9.00%
	Matching systems	47		47.00%
	Processing frameworks	21		21.00%
	Practical applications	13		13.00%
	Evaluation	6		6.00%
2012	Reviews	6	107	5.61%
	Matching techniques	9		8.41%
	Matching systems	52		48.60%
	Processing frameworks	23		21.50%
	Practical applications	15		14.02%
	Evaluation	2		1.87%
2013	Reviews	8	52	15.38%
	Matching techniques	6		11.54%
	Matching systems	16		30.77%
	Processing frameworks	9		17.31%
	Practical applications	10		19.23%
	Evaluation	3		5.77%

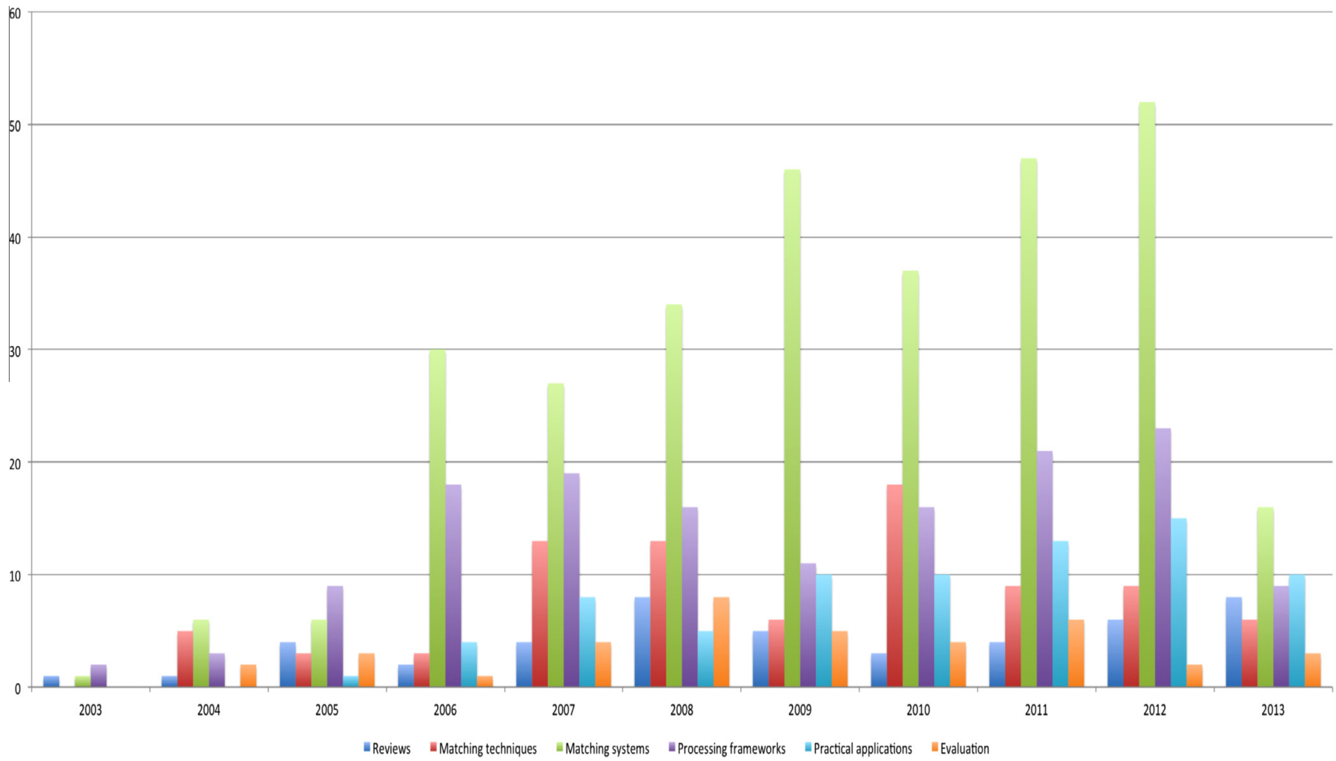

Fig. 5. Evolution of the different categories.

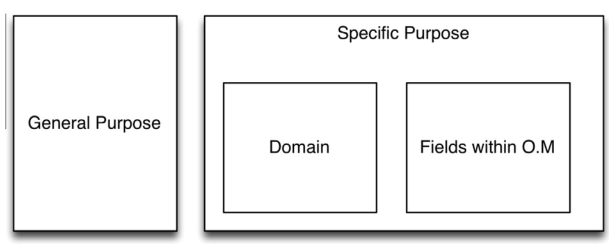

Fig. 6. Specific types of articles within 'Reviews' category.

– *Element-level matchers*: these techniques obtain the correspondences by considering the entities in the ontologies in isolation, therefore ignoring that they are part of the structure of the ontology.
– *Structure-level matchers*: these techniques obtain the correspondences by analyzing how the entities fit in the structure of the ontology.

In the second level of the classification, the techniques can be further classified as:

– *Syntactic*: these techniques limit their input interpretation to the instructions stated in their corresponding algorithms.
– *Semantic*: these techniques use some formal semantics to interpret their input and justify their results.

If reading the classification bottom-up, the elementary matching techniques can be initially divided in two categories determined by the *origin* of the information considered for the matching process:

– *Content-based*: these techniques focus on the internal information coming from the ontologies to be matched.
– *Context-based*: these techniques consider for the matching, external information that may come from relations between ontologies or other external resources (*context*).

In the second level of the classification, both categories are further refined. The *content-based category* is further divided into four new groups, depending on the input that the techniques use:

– *Terminological*: these methods consider their inputs as strings.
– *Structural*: these methods are based on the structure of the entities (classes, individuals, relations) found in the ontology.
– *Extensional*: these methods compute the correspondences by analyzing the set of instances of the classes (extension).
– *Semantic*: these techniques need some semantic interpretation of the input and usually use a reasoner to deduce the correspondences.

In the second level of the classification for the *context-based category*, the techniques can be also further classified as *syntactic* or *semantic* techniques.

The next level in any of both classifications already corresponds to the specific techniques. Following the different paths in this classification tree, several techniques may be reached. These categories were used to further sort the 49 articles belonging to *basic matching techniques*. The classification of these articles was particularly hard since most of them were not devoted to a single technique but to several, so in the following we provide an example of articles that match into some categories but it is worth noticing that many of them may also be included in another one.

- *Formal Resource-based*: these techniques use formal resources to support the matching process, such as upper level ontologies, domain-specific ontologies or the recorded alignments of previ-

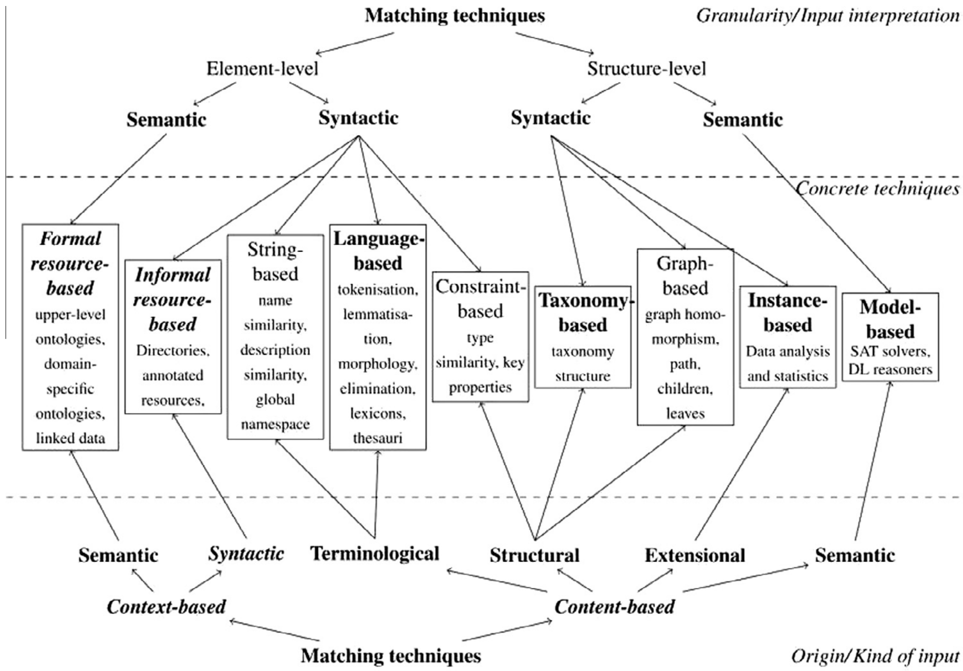

Fig. 7. Matching techniques classification. Extracted from the book *'Ontology Matching'* (Euzenat & Shvaiko, 2013).

ously matched ontologies (*alignment reuse*). Examples of such techniques are Scharffe, Zamazal, and Fensel (2013) and Mascardi, Locoro, and Rosso (2010).

- *Informal Resource-based*: these techniques, as those in the previous category, also exploit an external resource, but in this case the external resources are informal ones. This group of techniques deduce relations between ontologies using the relation between the ontologies and such informal resources. An example of such category could not be found among the results of the review.
- *String-based*: these techniques are based on the similarity of the strings that represent the names and descriptions of the entities in the ontologies. There are several string distance metrics that can be used in these methods *Levenshtein*, *Jaccard*, *Jaro-Winkler*, *Euclidean*, *TFIDF*, etc., (Cohen, Ravikumar, & Fienberg, 2003). Such techniques are present, for instance in the work of Akbari, Fathian, and Badie (2009).
- *Language-based*: these techniques rely on Natural Language Processing, as these do not consider names as simply strings but words in some natural language. Techniques in this category are, for example, *tokenisation*, *lemmatisation* or *stopword elimination*, some of which are applied by Shah and Syeda-Mahmood in Shah and Syeda-Mahmood (2004). This category also considers those techniques that take advantage from external resources to find similarities between terms, using for instance, *lexicons*, *dictionaries* or *thesauri*. In He, Yang, and Huang (2011) for instance, the *WordNet* (WordNet, 2013) database is used as the external resource.
- *Constraint-based*: these techniques consider criteria regarding the internal structure of the entities, such as the *domain and range of the properties* or the *types of the attributes*, to calculate the similarity between them. It is common to use these techniques in combination with others as in the work by Glückstad (2010).
- *Graph-based*: these techniques consider the ontologies to match as labelled graphs, or even trees, and treat the ontology matching problem as a graph homomorphism problem. An example of these techniques can be found in the paper from Joslyn, Paulson, and White (2009). This category also considers those techniques that exploit as external resources, repositories where ontologies and their fragments, together with certain similarity measures are stored. A proposal in this line can be found in the paper from Aleksovski, Ten Kate, and Van Harmelen (2008).
- *Taxonomy-based*: these techniques can be seen as a particular case of the previous ones which only consider the specialization relation. Examples were these techniques were applied could not be found in the articles belonging to *basic matching techniques*. However, an example of its application can be found in the work by Warin and Volk (2004).
- *Instance-based*: these techniques exploit the extension of the classes in the ontologies, i.e., the individuals, with the intuition that if the individuals are alike, then the classes they belong to should also be similar. These techniques can use set-theoretic principles but also more elaborated statistical techniques. In this category we can classify the work by Loia, Fenza, De Maio and Salerno presented in Loia, Fenza, De Maio, and Salerno (2013).
- *Model-based*: these techniques exploit the semantic interpretation linked to the input ontologies. An example of this category are the *description logics reasoning techniques*, which are applied in the work published by Sánchez-Ruiz, Ontañón, González-Calero, and Plaza (2011).

As mentioned at the beginning of this section, the techniques we have just presented, are the building blocks upon which (ii) *complex matching techniques* are built. This category includes *methodologies* that propose different ways to tackle the matching problem but from a higher point of view. Examples of this can be found in Cohen et al. (2003) where Cohen, Ravikumar and Fienberg propose the partitioning of the ontologies before starting the matching process, in Dargham and Fares (2008) where the Dargham and Fares present their methodology which takes as basis some well-known algorithms or in Acampora, Loia, Salerno, and Vitiello (2012) where Acampora, Loia, Salerno and Vitiello propose the use of a memetic algorithm to perform the alignment between two ontologies.

Other matching techniques also included in this category are those that can not be considered basic or that take advantage of other aspects of building a matching solution that are not directly related to computing the alignments. There are for instance articles devoted to presenting (i) different ways of aggregating the results from different similarity measures (Lai et al., 2010; Lin & Sandkuhl, 2007; Tian & Guo, 2010), others that (ii) combine the results of different matchers (Liu et al., 2012). There are others that also include techniques inherited from other fields such as (iii) learning methods (Rubiolo, Caliusco, Stegmayer, Coronel, & Fabrizi, 2012; Todorov, Geibel, & Kühnberger, 2010), probabilistic methods (Calı, Lukasiewicz, Predoiu, & Stuckenschmidt, 2008; Spiliopoulos, Vouros, & Karkaletsis, 2010) or those that consider the user's involvement (Lin & Sandkuhl, 2008b) in the matching process.

Despite the various types of matching techniques that have been presented in this section, both basic and complex ones, we are certain that many others will continue to arise. Some of these may offer a revisited version of previously exiting techniques, but more likely new types of techniques will be defined specially for those categories not fully explored yet. The main challenges these techniques face is their efficiency (Kotis & Lanzenberger, 2008; Shvaiko & Euzenat, 2013). Most of them describe approaches to matching ontologies which at a theoretical level may obtain a positive outcome. However, depending on the type of application where these techniques will be implemented, not all techniques will be equally valid. For instance, if considering a dynamic application, the amount of resources employed in terms of memory and time consumption should be kept to a minimum.

4.3. 'Matching Systems' category

This category contains the articles focused on detailing new matching algorithms and systems as well as enhancements, modifications or different approaches to previously defined ones. Some of these systems are well-known in the research community as they have participated for several years in the *Ontology Alignment Evaluation Initiative*. Although the purpose of this review is not to compile an exhaustive list of all the existing systems, it is worth mentioning some of the most relevant ones, such as:

- *AgreementMaker* (Cruz, Antonelli, & Stroe, 2009a) is a schema and ontology matching system. It allows a high customization of the matching process, including several matching methods to be run on inputs with different levels of granularity, also allowing to define the amount of user participation and the formats that the input ontologies as well as the results of the alignment may be stored in. This system has a high level of maturity because from 2007 there is a continuous flow of publications describing its foundations and enhancements: Sunna and Cruz (2007), Cruz, Antonelli, Stroe, Keles, and Maduko (2008), Cruz, Antonelli, and Stroe (2009b, 2009c), Cruz et al. (2010), Pesquita, Stroe, Cruz, and Couto (2010), Cross et al. (2011), Cruz, Stroe, Pesquita, Couto, and Cross (2011) and Cruz et al. (2011).
- *Anchor-Flood* (Hanif & Aono, 2009) is an algorithm for ontology matching that starts out of an initial anchor, i.e, a pair of alike concepts between the ontologies. From this anchor using neighborhood concepts, new anchors are identified and the algorithm continues. Anchor-Flood was developed from 2008 to 2009, having in this period a total of 3 reported papers, (Hanif & Aono, 2008a, 2008b, 2009). This system has been tested in two different campaigns of OAEI.
- *AOAS* (Zhang & Bodenreider, 2007) is an ontology matching system specifically devoted to aligning anatomical ontologies. It takes as input OWL ontologies and identifies 1:1, 1:n and n:m alignments. It is a hybrid approach that uses both direct techniques, such as lexical and structural ones, and indirect techniques, that consist in the identification of correspondences by means of a reference ontology. AOAS is a really specific system which, in the period from 2003 to 2013, only accounts for one publication, (Zhang & Bodenreider, 2007).
- *AROMA* (David, 2011) finds equivalence and subsumption relations between classes and properties of two different taxonomies. It is defined as an hybrid, extensional and asymmetric approach that lays its foundations on the association rule paradigm and statistical measures. AROMA's developers have been constantly working on it since 2006. There has been at least one paper published every year detailing this system and its evolution for the past 7 years. (David, Guillet, & Briand, 2006; David, 2007, 2008b, 2008a, 2011). This system has taken part in several editions of the OAEI.
- *ASCO* (Le, Dieng-Kuntz, & Gandon, 2004) exploits all the information available from the entities in the ontologies, names, labels, descriptions, information about the structure, etc, to compute two types of similarities, a linguistic and a structural one, which are lately combined. The development of ASCO started in 2004, however it was discontinued until 2007 when it was reprised. In this 3 year-span, the publications describing it are: Le et al. (2004) and Thanh Le and Dieng-Kuntz (2007).
- *ASE* (Kotis, Katasonov, & Leino, 2012a) is an automated ontology alignment tool based on AUTOMSv2 that computes equivalence and subsumption relations between two input ontologies. This system was released in 2012 and tested that year's edition of the OAEI. So far, we have not found any other publication apart from Kotis et al. (2012a), describing it. However it is possible that other enhancements may be developed as this system was already based on a previous system by the same authors for which there was also a significant interval between the first release and the subsequent updates.
- *ASMOV* (Behkamal, Naghibzadeh, & Moghadam, 2010) is an algorithm that derives an alignment from the lexical and structural information of two input ontologies by computing a similarity measure between them. This algorithm also includes a step of semantic verification where the alignments are checked so that the final output does not contain semantic inconsistencies. The greatest efforts in maintaining ASMOV were concentrated in 2008 when authors published Jean-Mary, Shironoshita, and Kabuka (2008) and Jean-Mary and Kabuka (2008), however, this system was constantly maintained from 2007 to 2010. In this period the following articles describe its features and performance: Jean-Mary and Kabuka (2007), Jean-Mary, Shironoshita, and Kabuka (2009, 2010) and Behkamal et al. (2010). Some of these articles detail the results obtained by ASMOV in the different editions it took part in.
- *AUTOMSv2* (Kotis, Katasonov, & Leino, 2012b) is an automated ontology matching tool that was build as an evolution of the previous tool AUTOMS (Kotis, Valarakos, & Vouros, 2006) which was enhanced with more alignment methods and synthesizing approaches as well as with multilingual support. Articles describing AUTOMSv2 were published in 2008 and 2012. This system shows one of the highest intervals of inactivity of the studied ones. Due to the short time interval from the last article, new articles describing AUTOMSv2 participation in OAEI or new versions could be published.
- *Coincidence-Based Weighting* (Qazvinian, Abolhassani, (Hossein), & Hariri, 2008) uses an evolutionary approach for ontology matching. It takes as input OWL ontologies, which are processed as graphs, and a similarity matrix between the concepts of the ontologies, obtained from a string distance measure. It includes a genetic algorithm to iteratively refine the mappings.

This system was developed for 2 years, since 2007 to 2008, as reflect the articles describing it, (Haeri, Abolhassani, Qazvinian, & Hariri, 2007; Qazvinian et al., 2008).

- *CIDER* (Gracia, Bernad, & Mena, 2011) is an ontology matching system that extracts the ontological context of the compared terms by using synonyms, hyponyms, domains, etc., and then enriches it by means of some lightweight inference rules. This system was developed using the *Alignment API* (David, Euzenat, Scharffe, & dos Santos, 2011). This system has been developed and maintained since 2008 to 2013. From the first paper describing it (Gracia & Mena, 2008) until the next one (Gracia et al., 2011), 3 years passed. Then again, publications regarding this system, were interrupted until last year with (Gracia & Asooja, 2013). This kind of systems developed over several years are usually the product of a deep effort of the developers to correct the issues detected in previous versions, and account for the time-span existing between the publication of the different articles.
- *CODI* (Huber, Sztyler, Nößner, & Meilicke, 2011) uses some lexical similarity measures combined with schema information to output the alignments between concepts, properties and individuals. It is based on the syntax and semantics of Markov logic, and turns every matching problem into an optimization problem. According to the data in our review, CODI was developed and maintained from 2010 to 2011. In these years it took part in the corresponding OAEI contests (Huber et al., 2011; Noessner & Niepert, 2010).
- *COMA* (Maßmann, Raunich, Aumüller, Arnold, & Rahm, 2011), *COMA++* (Nasir & Noor, 2010) are ontology matching systems that have been developed over the last decade. They are highly evolved and customizable systems that support the combination of different matching algorithms. These are highly evolved systems since they have been maintained and updated until 2011. In this period 5 articles were found, devoted to describing these systems, (Aumüller, Do, Massmann, & Rahm, 2005; Aumueller, Do, Massmann, & Rahm, 2005; Do & Rahm, 2002; Do, 2006; Engmann & Maßmann, 2007; Massmann, Engmann, & Rahm, 2006; Maßmann et al., 2011; Nasir & Noor, 2010).
- *DSSim* (Nagy, Vargas-Vera, & Stolarski, 2009) is an ontology matching system which combines the similarity values provided by both syntactic and semantic similarity algorithms to then refine the correctness of the outputs by means of a belief function. DSSim was developed from 2006 to 2009. In these 4 years, there was at least an article published every year detailing the system, its continuous enhancements, and its results in OAEI (Nagy, Vargas-Vera, & Motta, 2006, 2007; Nagy, Vargas-Vera, Stolarski, & Motta, 2008; Nagy et al., 2009).
- *Eff2Match* (Chua & Kim, 2010) is an ontology matching tool that follows a process of anchor generation and expansion. This system is particularly focused on achieving an efficient performance and therefore it includes several techniques to reduce the amount of possible candidates to avoid unnecessary comparisons. Considering the data obtained from our literature review, Eff2Match only has a related publication that was released in 2010 that presents its results for OAEI'10.
- *FalconAO* (Hu & Qu, 2008) obtains the alignment between the input ontologies by internally running two algorithms, a linguistic one (LMO) (Zhang, Hu, & Qu, 2011) as a first step, to then use the alignments provided as an external output for the graph matching algorithm (GMO) (Hu, Jian, Qu, & Wang, 2005) subsequently run. This system was continuously developed from 2005 to 2008 (Hu, Cheng, Zheng, Zhong, & Qu, 2006; Hu et al., 2007; Hu & Qu, 2008; Jian, Hu, Cheng, & Qu, 2005). In 2010, a new publication was released (Hu, Chen, Cheng, & Qu, 2010) with the results of this system in the OAEI.
- *FBEM* (Stoermer & Rassadko, 2009a) is a matching system that is mainly focused on instance matching, this approach considers not only the similarity of entity features as keys and values, but also the fact that some features are more relevant for identifying an entity than others. According to the data obtained in this review, this system is described in just 2 publications released in 2009 and 2010 respectively, (Stoermer & Rassadko, 2009b; Stoermer, Rassadko, & Vaidya, 2010).
- *FuzzyAlign* (Fernández, Velasco, Marsa-Maestre, & Lopez-Carmona, 2012) is a fuzzy, rule-based ontology matching system that outputs the alignments between two input ontologies by exploiting the lexical and semantical information of the entities' names and the inner structure of the ontologies. This system was developed from 2009 to 2012, however, it was not a constant maintenance, since in this period only 2 articles account for its updates and enhancements, (Fernández, Velasco, & López-Carmona, 2009; Fernández et al., 2012).
- *GeRoMeSuite* (Quix, Gal, Sagi, & Kensche, 2010) allows the matching of models represented in different languages, for instance XML Schemas with OWL ontologies. Besides it is a customizable system that includes several matching algorithms that may be combined according to different ways of aggregation and filtering. GeRoMeSuite is a mature system that has been developed from 2007 to 2010 (Kensche, Quix, Li, & Li, 2007; Quix, Geisler, Kensche, & Li, 2008, 2009; Quix et al., 2010). However, from 2010 to 2013 no new improvements were publicly released. It took part in OAEI editions from 2008 to 2010.
- *GLUE* (Doan, Madhavan, Domingos, & Halevy, 2004) is a semi-automatic ontology matching system that uses a set of combined machine learning techniques to output the alignment between the taxonomies of two input ontologies. This system only has a publication released in 2004, which made us believe that its development has been discontinued.
- *GOMMA* (Hartung, Kolb, Groß, & Rahm, 2013) uses several matchers to evaluate both the lexical and structural similarity of the entities from the input ontologies. It uses some enhanced comparison techniques to compute parallel string matching on graphical processing units. GOMMA was first released in 2011, and it has continued to be maintained up to date. The maturity level of this system is significative, as at least one publication regarding its results has been released every year since it was first developed (Groß, Hartung, Kirsten, & Rahm, 2012; Hartung et al., 2013; Kirsten, Gross, Hartung, & Rahm, 2011). This system has been tested so far in a edition of the OAEI, (Groß et al., 2012).
- *HCONE* (Kotis & Vouros, 2004) is an approach to ontology merging that uses WordNet (WordNet, 2013), a lexical database, as an external resource to obtain possible interpretations of the concepts being matched. HCONE was an stable system maintained from 2004 to 2006 (Kotis & Vouros, 2004; Kotis, Vouros, & Stergiou, 2006; Vouros & Kotis, 2005). After 2006 we could not retrieve any publication were it was used or modified.
- *Hertuda* (Hertling, 2012) is a very simple string matcher that separately handles the alignment of classes and properties, and select among the possible ones those reaching certain pre-established thresholds. Hertuda is a relatively young system which was released in 2012. Within the limits of this literature review only two articles were found that described its overall behavior and results in OAEI: Hertling (2012) and Grau et al. (2013).
- *HotMatch* (Dang et al., 2012a) combines several matching strategies, that exploit both the lexical and structural information, to obtain the alignments between the ontologies. Some filters are included to remove the false-positive mappings from the final

output. As happens with Hertuda, HotMatch is also a young system developed from 2012 up to date (Dang et al., 2012b; Grau et al., 2013), hence, new versions and enhancements are to be expected. This system, has also taken part in OAEI'12.

- *HMatch* (Castano, Ferrara, & Messa, 2006) is an ontology matching system that linearly combines a linguistic affinity value and a contextual affinity one to compute the similarity of concept names and contexts. Internally it codifies the ontologies as graphs. HMatch was developed from 2006 to 2009 (Castano et al., 2006; Castano, Ferrara, Lorusso, & Montanelli, 2007; Castano et al., 2008). According to the articles retrieved for this review, HMatch only took part in the edition of 2006 of the OAEI.
- *IF-MAP* (Kalfoglou & Schorlemmer, 2003a) is a matching system that lies its foundations on the mathematical theory of semantic information flow. To match two input ontologies it uses a reference ontology used as common reference. In the time-span considered in this literature review, only one article was found devoted to this system. Such publication was released in 2003, it is possible that there are other articles that had published before that, which would fall outside the scope of this review, anyhow, considering the time elapsed, we are prone to believing that this system has been discontinued.
- *iMatch* (Albagli, Ben-Eliyahu-Zohary, & Shimony, 2012) is a probabilistic ontology matching system based on Markov networks. It takes OWL ontologies as input and outputs 1:1 alignments. The matching is tackled as a graph matching problem where the initial similarity between the nodes is provided, for instance, by the users. iMatch was first released in 2009 (Albagli, Ben-Eliyahu-Zohary, & Shimony, 2009) and then revisited in 2012 (Albagli et al., 2012).
- *KOSImap* (Reul & Pan, 2010) uses description logic reasoning to firstly obtain implicit background knowledge for every entity in the ontologies, then build a similarity matrix out of the three types of similarities computed for the identified pairs of entities, and finally dismiss those mappings considered false-positives. KOSImap was only maintained for 2 years, since 2009, when it took part in the OAEI, (Reul & Pan, 2009) to 2010 (Reul & Pan, 2010).
- *LDOA* (Kachroudi, Moussa, Zghal, & Yahia, 2011) combines some well-known terminological and structural similarity measures, but it also exploits an external resource by using Linked Data which provides additional information to the entities being matched. In the interval considered in this literature review, we have only retrieved one article devoted to describing this system, in 2011, describing its behavior in the OAEI. As it is relatively contemporary, new enhancements and publications are still to be expected.
- *Lily* (Wang, 2011) combines different matching strategies to adapt itself to the problem being tackled at each moment, generic ontology matching (GOM) for the normal-sized ontologies and large scale ontology matching (LOM) for more demanding matching tasks. It also includes a mapping debugging function used to improve the alignment results and to dismiss the faulty ones. Lily was first released in 2007 (Wang & Xu, 2007) and continued to take part in the OAEI contests until 2011 (Wang & Xu, 2008; Wang & Xu, 2009; Wang, 2011). We consider that the reliability of this system has been enough proven as show the different results obtained in the OAEI.
- *LogMap* (Jiménez-Ruiz & Cuenca Grau, 2011) is an ontology matching iterative process that starting with a set on anchor mappings obtained from lexical comparison, alternatively computes mapping repair and mapping discovery steps. To discover the new anchors structural information is also exploited. This system has a high level of maturity as in the last 3 years there have been at least 6 publication describing its performance and results in the OAEI contests (Jiménez-Ruiz & Cuenca Grau, 2011; Jiménez-Ruiz, Grau, & Zhou, 2011; Jiménez-Ruiz, Morant, & Grau, 2011; Jiménez-Ruiz, Grau, & Horrocks, 2012; Jiménez-Ruiz, Meilicke, Grau, & Horrocks, 2013). In this period LogMap's developers have already implemented a light version of LogMap, *LogMaplt*. We are prone to believing that developers of this system will continue to improve it and include further functionalities and versions.
- *MaasMatch* (Schadd & Roos, 2012a) computes a similarity cube between the concepts in the ontologies which is the result of aggregating a syntactic, a structural, a lexical and a virtual document similarity. An extraction algorithm is run to dismiss the faulty alignments from the final output. This system has been constantly updated since it was first released in 2011, its reliability and usefulness have been tested over the years by its participation in the OAEI (Schadd & Roos, 2011, 2012a, 2012b, 2013).
- *MapPSO* (Bock, Dänschel, & Stumpp, 2011) applies the particle swam optimization technique (PSO) to compute the alignment between two input ontologies. The *MapEVO* (Bock et al., 2011) system, developed by the same authors, relies on the use of evolutionary programming, another variant of population-based optimization algorithms. MapPSO has been described in at least 5 different publications between 2008 and 2011. Among those systems revised, MapPSO is one of those with the higher amount of publications (Bock & Hettenhausen, 2008, 2010; Bock, Liu, & Hettenhausen, 2009; Bock, 2010; Bock, Lenk, & Dänschel, 2010; Bock et al., 2011). These publications include the participation of MapPSO in editions of OAEI from 2008 to 2011.
- *MapSSS* (Cheatham, 2011) computes subsequently three types of metrics, syntactic, semantic and structural, and any positive result from any of them is included as a positive solution, and then it explores the neighborhood of the newly matched pair for new possible matches. Instead of defining a filtering system which would dismiss possible pair after being selected, this system works the other way round only selecting those nodes that match to only another node, and therefore not risking the possibility of choosing a wrong solution. This system was released in 2011, and, ever since it took part in the annual contest of the OAEI. This system has been therefore significantly tested and evaluated (Cheatham, 2011; Cheatham & Hitzler, 2013).
- *MEDLEY* (Hassen, 2012) is an ontology alignment system that uses lexical and structural methods to compute the alignment between classes, properties and instances. It also uses an external dictionary to tackle the problem of having concepts expressed in different natural languages. This system was described in 2012 in Hassen (2012) where the results of its participation in that year's OAEI are summarized. Other publications, as well as its participation in new OAEI editions, are to be expected because this system quite recent.
- *MoTo* (Fanizzi, d'Amato, & Esposito, 2011) takes OWL ontologies as input and obtains equivalence relations between concepts. It initially uses several matchers whose results are combined by means of a metalearner. The alignments obtained are sorted, discarding those invalid ones. The remaining are divided into certain and uncertain. For the uncertain ones a validation process is started aiming at recovering them. In this literature review we have found publications describing this system both in 2010 (Esposito, Fanizzi, & d'Amato, 2010) and 2011 (Fanizzi et al., 2011), but so far, no other publication has been released.
- *OACAS* (Zghal, Kachroudi, Yahia, & Nguifo, 2011) is an algorithm to align OWL-DL ontologies. It firstly transforms the ontologies into graphs and then it combines and aggregates different similarity measures. At each moment the most suitable similarity measure is applied according to the type of the entities being matched. It also exploits the neighboring relations of the entities. The first article describing OACAS was published in 2009 (Zghal, Kachroudi, Yahia, & Nguifo, 2009), then until 2011 no

new articles were retrieved (Zghal et al., 2011). Therefore, considering the two-year span between both, it is possible that new articles will be published within this or the next year. This system was publicly tested in the OAEI'11.

- *OLA* (Kengue, Euzenat, & Valtchev, 2007) performs the alignment between two graph-represented ontologies and offers some extended features to manipulate the output alignment. This system was developed between 2004 (Euzenat & Valtchev, 2004) and 2005 (Euzenat, Guégan, & Valtchev, 2005), later, it was revisited in 2007 (Kengue et al., 2007). In this interval, it took part in the OAEI of 2005 and 2007. However, so far, it has been 6 years where no additional articles regarding OLA were retrieve by means of the queries run for this literature review.
- *oMap* (Straccia & Troncy, 2005c) automatically aligns two OWL ontologies by using the prediction of different classifiers, such as terminological, machine learning-based, or some based on the structure and semantics of the OWL axioms. This system was deeply revised in 2005 (Straccia & Troncy, 2005a; Straccia & Troncy, 2005c; Straccia & Troncy, 2005b) when it was released and then in 2006 (Straccia & Troncy, 2006). In 2005 it took part in the OAEI, however, ever since, no new articles describing oMap have been published.
- *OMEN* (Mitra, Noy, & Jaiswal, 2005) uses a Bayesian Network to improve the results of the alignment process by deriving undetected correspondences and rejecting existing false positives. By using probabilistic methods it enhances existing ontology mappings by deriving missed matches and invalidating existing false matches. This system was described in just one paper in 2005 (Mitra et al., 2005).
- *OntoDNA* (Kiu & Lee, 2007) is an automated and scalable system that uses hybrid unsupervised clustering techniques, which include Formal Concept Analysis (FCA) (Formica, 2006), Self-Organizing Map (SOM) and K-Means clustering, in addition to a Levenshtein edit distance as lexical measurement. OntoDNA was first described in 2006 (Kiu & Lee, 2006) and then revisited in 2007 to present its results in the OAEI (Kiu & Lee, 2007).
- *ontoMATCH* (Lu, 2010) exploits both semantic and structural information to compute the alignments. It is internally divided into five components, a preprocessor, three individual matchers (Element Matcher, Relationship Matcher and Property Matcher), a combiner and a selector. This system was described in one paper in 2010 (Lu, 2010).
- *OPTIMA* (Thayasivam et al., 2012) uses lexical information from the concepts to generate a seed alignment. Then it iteratively searches the space of candidate alignments following the technique of expectation–maximization until convergence. This system was presented in 2011 taking part at the OAEI (Thayasivam & Doshi, 2011). It also took part in the following year's contest (Thayasivam et al., 2012).
- *OWL-CM* (Yaghlane & Laamari, 2007) uses different matchers to compute the alignments, whose results are then combined. It also includes some belief functions into the alignment process to improve the computed results. In this literature review we only retrieved one article in 2007 (Yaghlane & Laamari, 2007).
- *PRIOR+* (Mao & Peng, 2007) is an ontology matching system that lays its foundations on propagation theory, information retrieval and artificial intelligence. It profits the linguistic and structural information of the ontologies to match and measures the profile similarity of different elements in a vector space model. This system took part in the editions of 2006 (Mao & Peng, 2006) and 2007 (Mao & Peng, 2007) of the OAEI where its results and performance are described.
- *QOM* (Ehrig & Staab, 2004) is a variation of the *NOM* algorithm devoted to improving the efficiency of the system. Some basic matchers are used whose results are refined by means of a sigmoid function, to be lately aggregated and sifted to output the final alignment. This system was developed in the first years of the interval considered in this literature review in 2 papers (Ehrig & Staab, 2004; Ehrig & Sure, 2004).
- *RiMOM* (Wang et al., 2010) uses three different matching strategies, name-based, metadata-based and instance-based, whose results are then filtered and combined. A similarity propagation procedure is iteratively run until no more candidate mappings are discovered and the system converges. Within the limits of this review, RiMOM is the system that accounts for the highest number of individual publications describing it, 9. These articles span from 2004 to 2013. In this period, there have been periods of interruption in the flow of publications, however we believe they account for the development of a new version of the system (Li, Li, Zhang, & Tang, 2006; Li, Zhong, Li, & Tang, 2007; Li, Tang, Li, & Luo, 2009; Tang, Liang, Li, & Wang, 2004; Tang et al., 2006; Wang et al., 2010; Zhang, Zhong, Li, & Tang, 2008; Zhang, Zhong, Shi, Li, & Tang, 2009). RiMOM has taken part in several editions of the OAEI, therefore it has been tested and evaluated over several years.
- *SAMBO* (Lambrix, Tan, & Liu, 2008) contains several matchers that exploit different features of the ontologies, and it is the user the one who decides to use one or several. If several are chosen the combination of the results by each of them are computed by means of a weighted sum. Results are then filtered according to some thresholds and presented to the user as suggested alignments to be confirmed. This system has been maintained from 2005 to 2008. In this period, at least 5 different articles were published describing its performance and its results in the OAEI (Lambrix & Tan, 2005, 2006; Lambrix et al., 2008; Tan, Jakoniene, Lambrix, Aberg, & Shahmehri, 2006; Tan & Lambrix, 2007).
- *SEMA* (Spiliopoulos, Valarakos, Vouros, & Karkaletsis, 2007) combines six different matching methods whose running sequence is pre-established and where each method takes as input the results of the previous methods. This procedure is iteratively applied until no new mappings are discovered. The matchers used a are lexical matcher, a latent features matcher, a vector space model matcher, an instance based matcher a structural based matcher and a property based matcher. SEMA was described in 2 different articles in 2007 (Spiliopoulos et al., 2007), one of them presenting its results in the OAEI contest (Spiliopoulos et al., 2007).
- *SERIMI* (Araújo, de Vries, & Schwabe, 2011c) is a matching system developed for instance matching, which is mainly divided into two phases, a selection one and a disambiguation one. During these phases information retrieval strategies and string matching techniques are applied. This system was described in 4 articles between 2011 and 2012 (Araújo, Hidders, Schwabe, & de Vries, 2011a, 2011b; Araújo, Tran, DeVries, Hidders, & Schwabe, 2012). In 2011 it also took part in the OAEI (Araújo et al., 2011c).
- *ServOMap* (Ba & Diallo, 2013) is a large scale ontology matching system that also supports multilingual terminologies. It uses an Ontology Server *(ServO)* and takes advantage of Information Retrieval techniques to compute the similarity between the entities in the input ontologies. This system was recently developed, in 2012 (Ba & Diallo, 2012a, 2013; Diallo & Ba, 2012). However it has already taken part in the OAEI (Ba & Diallo, 2012b). This points out that developers are actively working on the maintenance of this system, therefore new improvements are to be expected, in addition to those already released in 2013 (Diallo & Kammoun, 2013; Kammoun & Diallo, 2013).
- *SIGMa* (Lacoste-Julien et al., 2013) is a knowledge base iterative propagation alignment algorithm that uses both the structural information from the relationship graph as well as some similarity measures between entity properties. SIGMa is also one

of the systems that can be considered as young since the first publication where it is described is from 2012 (Lacoste-Julien et al., 2012). This system is being actively maintained, and a new publication was released in 2013 (Lacoste-Julien et al., 2013).

- *S-Match* (Giunchiglia, Autayeu, & Pane, 2012) is an open source semantic matching framework that transforms input tree-like structures such as catalogs, conceptual models, etc., into lightweight ontologies to then determine the semantic correspondences between them. It contains the implementation of several semantic matching algorithms, each one suitable for different purposes. The amount of publications describing S-Match is one of the highest among those considered for this review, 7. This system has been maintained since 2003, however it was not a steady process, as the last publications have intervals between them of at least 2 years (Giunchiglia, Shvaiko, & Yatskevich, 2004, 2005a, 2005b; Giunchiglia, Yatskevich, & Shvaiko, 2007; Giunchiglia et al., 2012; Shvaiko, Giunchiglia, & Yatskevich, 2009).
- *SOBOM* (Xu, Wang, Cheng, & Zang, 2010a) is an ontology matching algorithm that uses as start point a set of anchors provided by a lexical matcher. It also uses the Semantic Inductive Similarity Flooding algorithm to compute the similarity between the concepts of the sub-ontologies obtained from the anchors. SOBOM has been described in publications ranging from 2008 to 2012 (Xu, Tao, Zang, & Wang, 2008; Xu et al., 2010a; Xu, Wang, Cheng, & Zang, 2010b; Xu, Wang, & Liu, 2012), including those of its participation in several editions of OEAI. In the two-year period from 2010 to 2012, no publications were retrieved regarding this system. As the last article dates from 2012, new updates and enhancements are still to be expected.
- *SODA* (Zghal, Yahia, Nguifo, & Slimani, 2007) uses linguistic and structural similarity measures to compute the alignment between two OWL-DL ontologies which are firstly transformed into graphs. This graphs undergo two successive phases, first a linguistic similarity comparison and then a structural similarity comparison, after which the semantic similarity of the graphs is obtained. This algorithm outputs the correspondences between the entities together with their similarity measure values. So far, only one article describing SODA was found (Zghal et al., 2007), published in 2007.
- *TaxoMap* (Hamdi, Safar, Niraula, & Reynaud, 2010) provides an alignment for two OWL ontologies by exploiting the information in the labels of the concepts and the subsumption links that connect those concepts in the hierarchy. TaxoMap has been maintained since it was released in 2007 up to 2010. In this interval, 6 articles were published describing the system and its participation in the OAEI (Hamdi, Zargayouna, Safar, & Reynaud, 2008; Hamdi, Safar, Niraula, & Reynaud, 2009; Hamdi et al., 2010; Safar & Reynaud, 2009; Safar, 2007; Zargayouna, Safar, & Reynaud, 2007).
- *TOAST* (Jachnik, Szwabe, Misiorek, & Walkowiak, 2012) is an ontology matching system based on statistical relational learning. This system needs a train set from which to learn the semantics equivalence relation on the basis of partial matches. TOAST is another system, considered young, as all the publications describing it were found for 2012 (Szwabe, Misiorek, & Walkowiak, 2012). However, this system has already taken part in the OAEI (Jachnik et al., 2012). If the developers continue with this trend, new articles on this system are to be expected.
- *WeSeE-Match* (Paulheim, 2012) exploits the idea of using information available on the web to match the ontologies which would supposedly be the procedure followed by a human trying to manually match some terms without being an expert in the domain of the matched terms. Therefore this approach uses a web search engine to retrieve documents relevant to the concepts to match and compare the results obtained, the more similar the search results, the higher the concepts' similarity value. This system accounts for few publications, however these report the results obtained by the system in the OAEI of 2012 and 2013 (Paulheim, 2012; Paulheim & Hertling, 2013).
- *WikiMatch* (Hertling & Paulheim, 2012a) exploits the use of *Wikipedia's* search engine to obtain documents related to the concepts being matched. Since there is no duplicity in the titles names of the articles in Wikipedia for the same language, the algorithm compares the sets of retrieved titles to obtain the similarity between the two concepts. As happens with WeSeE-Match, WikiMatch has been only described so far in two articles, although these are quite recent. One of them presenting its overall behavior (Hertling & Paulheim, 2012a) and the other reporting its results for the OAEI'12 (Hertling & Paulheim, 2012b).
- *X-SOM* (Curino, Orsi, & Tanca, 2007b) combines the similarity maps output by different matching algorithms by means of a neural network and uses logical reasoning and heuristics to enhance the quality of the mappings. This system was developed between 2007 and 2010, adding up a total of 4 articles (Curino, Orsi, & Tanca, 2007a; Curino et al., 2007b; Merlin, Sorjamaa, Maillet, & Lendasse, 2009; Merlin, Sorjamaa, Maillet, & Lendasse, 2010), including those that describe its participation in OAEI'07.
- *YAM++* (Ngo & Bellahsene, 2012a) uses machine learning techniques to discover the mappings between entities in two ontologies, even if these are not expressed in the same natural language. It uses matchers at element and structural level. At element level the similarity is computed by some terminological metrics which can be combined by machine learning based combination methods. At structural level the ontologies are transformed into graphs and considering the results of the terminological metrics as the starting points, a similarity flooding algorithm propagation is run. This system has a high level of maturity as it has been continuously evolving since 2009 up to 2013 (Duchateau, Coletta, Bellahsene, & Miller, 2009b, 2009a; Ngo, Bellahsene, & Coletta, 2011; Ngo & Bellahsene, 2012a, 2012b, 2013). In this period, at least 6 articles describing its behavior and overall results in the different editions of the OAEI have been published. Hence its validity and maturity is well proven.

Further considering the evolution and maturity degree of these systems, in Table 5 the amount of articles published regarding each one of the presented systems is shown. These values show a varying level of development in the different systems, as the amount of publications ranges from 1 to 9. In Fig. 8 these results are disaggregated by year. As it suggests, systems are devoted on average 2.6 years of work, which are usually consecutive. However, as happens, for instance, with *ASCO* the work was interrupted and resumed 3 years later. In other systems, as *RiMOM*, this discontinuation in the amount of publications accounts for the development of a new version.

4.4. 'Processing Frameworks' category

This category covers two types of publications, articles devoted to researching the *processing and exploiting of the ontology alignments* (25.85%) and also those that describe some *enhanced alignment frameworks and alignment formats* (74.10%).

Among those articles devoted to processing and exploiting the alignments, the most common topics were related to (i) *ontology merging* (Kim, Kim, & Chung, 2011), i.e., integrating two ontologies from different sources into a single new one with the information from both of them, (ii) *ontology transformation* (Šváb-Zamazal,

Table 5
Amount of articles yearly devoted to each system.

System	Articles
AgreementMaker	9
Anchor-Flood	3
AOAS	1
AROMA	8
ASCO	2
ASE	1
ASMOV	5
AUTOMSv2	2
CBW	2
CIDER	3
CODI	2
COMA	5
DSSim	4
Eff2Match	1
FalconAO	5
FBEM	2
FuzzyAlign	2
GeRoMeSuite	4
GLUE	1
GOMMA	3
HCONE	3
Hertuda	2
HotMatch	2
Hmatch	3
IF-MAP	1
iMatch	2
KOSImap	2
LDOA	1
Lily	4
LogMap	6
MaasMatch	3
MapPSO	5
MapSSS	3
MEDLEY	1
MoTo	2
OACAS	2
OLA	3
oMap	4
OMEN	1
OntoDNA	2
ontoMATCH	1
OPTIMA	2
OWL-CM	1
PRIOR+	2
QOM	2
RiMOM	9
SAMBO	5
SEMA	2
SERIMI	4
ServOMap	5
SIGMa	2
S-Match	7
SOBOM	4
SODA	1
TaxoMap	6
TOAST	2
WeSeE-Match	2
WikiMatch	2
X-SOM	4
YAM++	6

Svátek, & Iannone, 2010), that implies expressing an ontology with respect to another one, (iii) *reasoning* (Zhang, Lin, Huang, & Wu, 2011), that involves using the correspondences between the ontologies as rules for reasoning with them, and (iv) *alignment argumentation* (Trojahn, Quaresma, & Vieira, 2012), that is a way of explaining the alignments by providing arguments to support or dismiss them.

Despite the remarkable variety of topics in the articles from this sub-category, they represent a small percentage of the processing frameworks category, which in their majority were focused mainly on defining and developing *alignment frameworks* such as (Noy & Musen, 2003), where the process does not finish with the alignment but other actions are also available for the user, like manipulating the alignments or performing some of the procedures previously mentioned.

4.5. 'Practical Applications' category

The articles in this category present articles where ontology matching has been applied to a real-life problem. Within this category we found articles devoted to different subjects such as (i) *semantic web and web services* (Di Martino, 2009) where most publications presented ways of using ontology matching for service discovery or service composition, (ii) *P2P systems* (Atencia, Euzenat, Pirrò, & Rousset, 2011), where ontology matching was used as a way to reduce the semantical heterogeneity between the queries the users pose to the system and the documents stored, therefore improving the accuracy of the returned results. Other fields worth mentioning are (iii) *learning systems* (Arch-int & Arch-int, 2013), that focus the use of ontology matching techniques either on narrowing down the distance between the user's and the stored documents or as a way to ease the knowledge share and reuse among users, and last, (iv) *multi-agent systems* (Mascardi, Ancona, Bordini, & Ricci, 2011), where the use of ontology matching has always been related to guaranteeing that the different agents in a communication process could be actually able to interact and achieve the common goals.

In spite of the growing tendency in the development of practical applications, in general lines, it does not reach the 30% of the matching systems implemented each year, as Fig. 9 reflects. This situation is quite remarkable as it suggests that only a slight part of the matching systems developed have a practical application in real-life projects. To clarify this situation we have conducted a survey among ontology matching practitioners, where we asked them mainly about the future challenges of the field and its application in real-life projects. The description and results of this survey are further detailed in Section 6.

4.6. 'Evaluation' category

Out of the articles for this literature review, 38 are devoted to evaluating the performance of the matching systems. We can split these articles into two categories regarding the scope of the articles. There are 14 articles (36.84%) focused on studying the performance measures and on proposing different alternatives to evaluate the matching systems. We have included such articles in a category named *elementary approaches*.

The remaining 24 articles (63.16%) delve into *evaluation methods* were different existing platforms, systems or benchmarks to evaluate the matching systems are explored.

Regarding the (i) *elementary approaches* several articles explore alternatives to the well-known information retrieval measures of *precision* and *recall* which are used in this field to evaluate respectively the correctness and completeness of the matching systems. Examples of such publications are the works by Paulheim, Hertling and Ritze (Paulheim, Hertling, & Ritze, 2013), Niu, Wang, Wu, Qi and Yu (Niu, Wang, Wu, Qi, & Yu, 2011) or Euzenat (Euzenat, 2007). Additionally in this category we have also included those papers that describe a new evaluation *method* or *approach* such as the ones by Ferrara, Nikolov, Noessner and Scharffe (Ferrara, Nikolov, Noessner, & Scharffe, 2013) and by Tordai, van Ossenbruggen, Schreiber and Wielinga (Tordai, van Ossenbruggen, Schreiber, & Wielinga, 2011).

These measures and approaches are usually included as part of the systems proposed to evaluate the matching systems which are included in the (ii) *evaluation methods* category. In this category we have included those papers delving into the different existing

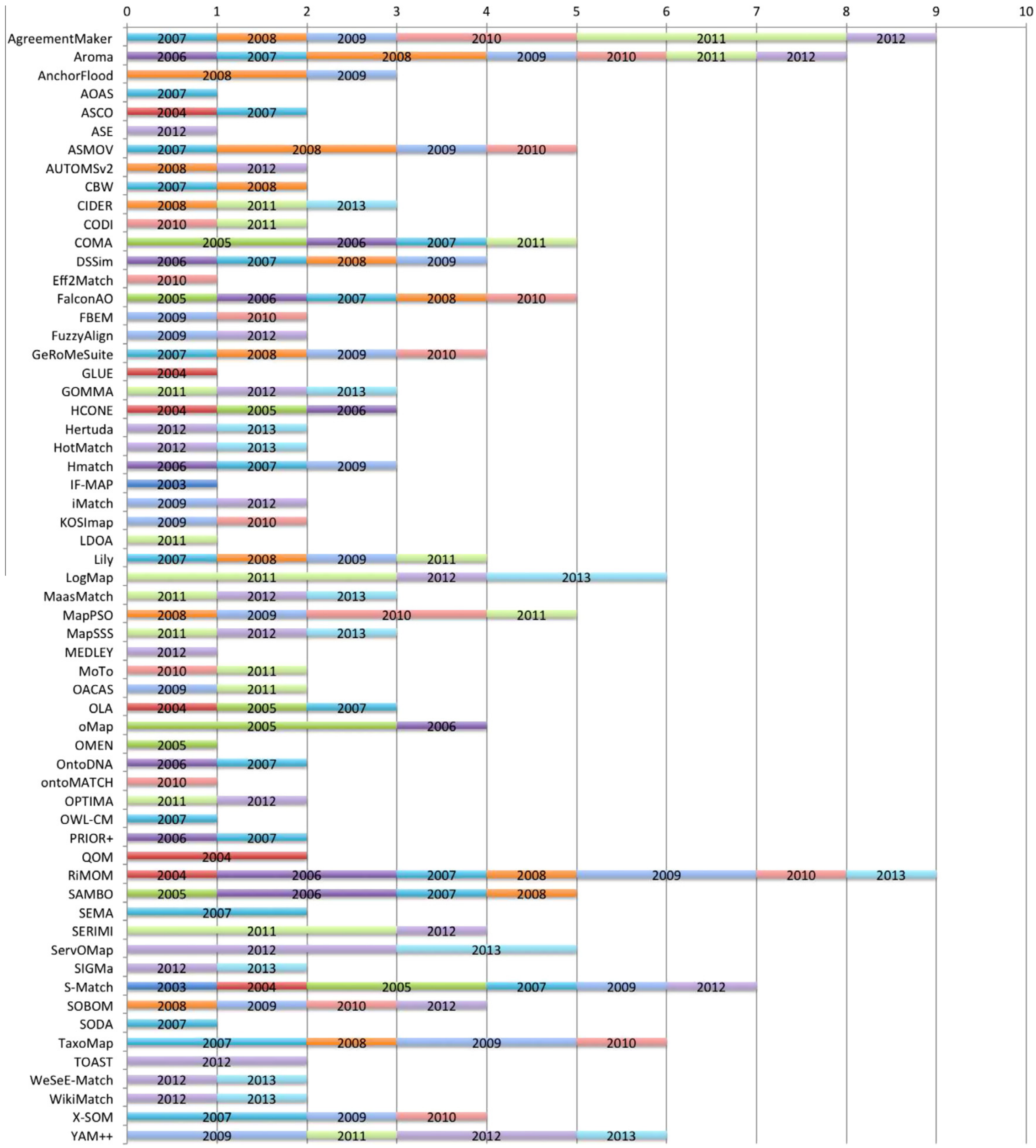

Fig. 8. Evolution of the systems over the years.

platforms, systems and benchmarks used for evaluation, as well as the results of evaluating the most widespread systems against these benchmarks or in these platforms.

Regarding the data sets or benchmarks for evaluation, the most well-known and used are those developed for the *Ontology Alignment Evaluation Initiative* which has been taken as a reference since 2004 (Euzenat, Stuckenschmidt, & Yatskevich, 2005) and that has been evolving over the years (Rosoiu, dos Santos, & Euzenat, 2011). This initiative contains various tracks with different data sets which evaluate several features of the tested systems.

The *benchmark test* (Euzenat, Roşoiu, & Trojahn, 2013) is built around a seed ontology and many variations of it, and its purpose is to provide a stable and detailed picture of the contesting algorithms. These tests are organized into *simple tests*, where the objective is to compare the original ontology with itself, a random one and a generalization, *systematic tests*, where the original ontology is to be compared with others where some modifications have been included, such as removing names, translating into other languages, flattening or expanding the hierarchy, etc., and finally, *real-life ontologies*. The *anatomy track* evaluates the matching systems with the task of matching two large ontologies, the Adult Mouse Anatomy and part of the NCI Thesaurus which describes the human anatomy. The *conference track* contains different ontologies from the conference organization domain. The interest of this track lies in the fact that these ontologies have been independently defined. The *MultiFarm track* aims at testing the ability of the systems to deal with multilingualism. The *library track* is a real-world task to match two thesaurus, the STW and the TheSoz, both used in libraries for indexation and retrieval. The *interactive track* tests the results obtained by the systems when the user is somehow involved. The *Large BioMed track* consists of finding alignments between the Foundational Model of Anatomy (FMA, 2013), SNOMED Clinical Terms (SNOMED, 2013), and the National Cancer Institute Thesaurus (NCI, 2013). Finally, the Instance Matching track focus its efforts on instance matching systems and techniques.

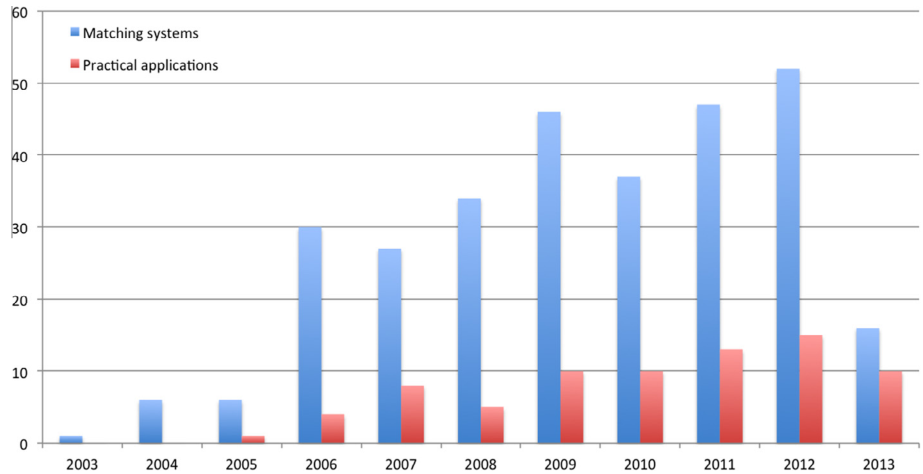

Fig. 9. Evolution of matching systems vs. practical applications.

Besides the benchmarks, in this category we have also included some actual systems used to evaluate the matching systems such as Wrigley, García-Castro, and Nixon (2012) and Tyl and Loufek (2009).

In this section we have presented our classification framework and further detailed the results of classifying the retrieved articles with this classification framework. In the following section we analyze the limitations to this review.

5. Limitations of the Literature Review

A literature review in the field of ontology matching is a very demanding task firstly due to the amount of background knowledge necessary to properly sort the identified articles, and secondly by the extent of the subject itself and the number of fields where the research on ontology matching is used.

The articles studied for this review were retrieved by querying online databases with different expressions regarding the ontology matching field. In spite of the high amount of articles retrieved, over 1600, it is possible that many others have not been recovered as we are dealing with a very wide field of knowledge.

Other databases besides those queried for this review, could have also been used to raise the amount of retrieved articles and broaden the scope of the review, however, the databases used are considered as the most relevant ones among the practitioners. In addition only those articles in english were finally included even though some publications were written in other languages, as we considered english as the predominant language regarding the research community.

In spite of the limitations previously described, this paper makes a brief review of the ontology matching field between 2000 and 2013. The articles written in this period were also sorted according to a classification framework which has allowed us to identify the different topics and problems that researchers were tackling for the last decade. Nevertheless this has also brought up several questions regarding the current research interests of researchers and practitioners, mainly whether they have continued to research on the same topics or not, and to check, for instance, if they have changed topic or even field. Another main issue that we have detected is the fact that, in the last decade lots of different matching systems and techniques have been developed, however, we could not state their use in real-life applications.

In order to clarify these doubts we have designed and performed a survey among the researchers. Its structure as well as the results of this survey are detailed in Section 6.

6. Trends in Ontology Matching: Practitioner-oriented Survey

We conducted a survey to clarify those concerns emerged from our literature review. Such concerns were mainly related to the current state of the research on ontology matching and its application in real-life projects.

6.1. Participants and Survey design

The participants in the survey were selected among those taking part at the OAEI contests. In a two month period, from December 2013 to February 2014, they were individually contacted by email and presented with the questionnaire shown in Table 6. Even though the participants were directly contacted by email, their identities and responses were strictly confidential and only available to the team conducting the survey. Out of the 288 experts contacted, we received 46 replies.

The survey was designed with 8 short open-ended questions. Although we have initially considered to define some of these questions as multiple-choice, we discarded that idea as we did not want to influence at any degree in the answers provided by the participants.

These questions can be classified into three groups. Questions 1 to 3 are *background questions*, questions 4, 5 and 7 are *research field questions* and questions 6 and 8 are *future challenges questions*.

The *background questions* were included in the questionnaire to assess the suitability of the participants and contextualize the answers they may provide. The *research field questions* were designed to gain knowledge about the current fields and topics that have become more attractive to the research community, and finally *future challenges questions* were designed to identify according to practitioners' point of view the main challenges that are still to be addressed and the potential expansion fields for ontology matching.

6.2. Survey results

Out of the 46 answers that we received, only 5 declined the participation in the survey, one answered it partially and 13 have not been researching on ontology matching for a while. Out of this researchers that have stopped working in the field, some of them have recently stopped and they answered the questionnaire anyhow, as their contribution was still relevant while others suggested a more appropriate contact within their groups to redirect the requests, half of which were answered back. To sum up, the initial

Table 6
Questionnaire used for the survey.

Number	Question	Type
1.	How long have you been researching in Ontology Matching?	Background
2.	What are your main purposes to do it?	Background
3.	How many research papers have you written on topics related to Ontology Matching?	Background
4.	Within the Ontology Matching field, in which particular topic are you currently working on?	Research field
5.	From your point of view, which are the main fields where the research on Ontology Matching is currently being applied?	Research field
6.	According to your expertise, which are the main challenges that are still to be addressed?	Future challenges
7.	Will you continue to research in Ontology Matching?Why?	Research field
8.	In which fields do you believe that Ontology Matching could also be used?	Future challenges

amount of replies was cut down to 33 actual answers with profitable information.

6.2.1. Background questions

The background of the participants in the research is quite broad and varied, and it includes different types of researchers in the field. From a temporal point of view, there are those who have started in the field more than a decade ago but also those who have recently started to work in this field, specifically values range from 1 to 14 years. Most of the practitioners (78.12%) who answered this questionnaire have been researching in the field for over 5 years, being the average number of years working in the field is slightly superior to 7.

In Fig. 10, the number of years researching in the field is shown in relation to the number of researchers.

Moreover some researchers have directly tackled the ontology matching problem by focussing on very specific topics such as *assessing the impact of using different similarity metrics in different ontology matching tasks*, *aligning large ontologies* or *improving ontology matching by using reasoning*, while others arrived to ontology matching as a support tool for matters such as *data integration*, *semantic interoperability* or *telecommunications systems interoperability*.

Anyhow the suitability of the participants is more than satisfactory as they account on their own for above 460 publications of different types linked to this subject.

6.2.2. Research field questions

The research field questions were included in the questionnaire to learn about the fields where respondents are working, as well as, the fields where they think ontology matching could also be applied. Out of the answers sent by the participants, we could determine that a high percentage of them (63%) is working in any of these four topics: *instance matching*, *user involvement in the matching process*, *data interlinking* and *discovery of different types of correspondences, not 1:1 equivalence relations*. The rest of the respondents mentioned other topics such as *parallel ontology matching*, *large-scale ontology matching*, *ontology matching negotiation* and *mapping reuse*, which are more specific. However, besides these main research topic, most respondents included *similarity metrics* and *combinations of methods to improve the coverage of ontology matching* as a way to enhance or support their other research interests.

Regarding the question about the fields where ontology matching is being applied, the consensus shown was noticeable. This question provided mainly two types of answers. From a practical point of view, respondents agree that *the medical and life science domain* is the one that is using ontology matching the most. Other researchers offered a more theoretical type of answers, mostly mentioning *data integration and interoperability* as the fields where ontology matching is being applied.

We have found really meaningful that several researchers pointed out that nowadays the use of ontology matching techniques is reserved to spot cases and that the research at this time seems merely foundational. However, they also agree that ontology matching can be applied in any field where there are two parties that need to communicate and that employ potentially different protocols, being this way the list of use cases potentially long.

Finally, when questioned about whether they would continue to research on this field, the majority, 63.64%, confirmed they would follow with present or related research lines claiming as reasons for instance, that *there are still plenty of challenges to address* and that *the development of new domains will sparkle new matching problems*. On the contrary, 30.30% of the respondents stated that they would, if not yet, change subjects. Among the reasons to do so, some mentioned they have moved to other related fields such as *linking open information systems* or *knowledge transformation*, while others definitely quit the field claiming the *lack of usefulness for real applications* or *the little incentive coming from the application side*. A small percentage, 6.06% were still considering whether to change subject or not.

6.2.3. Future challenges questions

These group of questions were included in the questionnaire to gain knowledge about how practitioners see the future evolution of the field and the main challenges still to be addressed. These answers provided are really useful as they identify a variety of challenges to address and quote several new fields where matching techniques could also be used and hence they could be used to guide the research lines adopted by different research groups.

Regarding the main challenges still to be addressed in the ontology matching field, most respondents agree on the need to *automatically discover complex relations, instead of 1:1*, to *correctly align large ontologies* and to *focus on applying automatically created mappings to practical applications*.

Other topics that arose in the responses were not supported by so many respondents but they point out anyway challenges that need to be addressed, such as:

1. Automated acquisition of reference alignment for evaluating large scale matching systems.
2. Creating large datasets to asses matching algorithms.
3. Define good tools that are easy to use for non-experts.
4. Develop high quality and fast intelligent combinations of string-based and new semantic-similarity measures.
5. Holistic ontology matching.
6. How to effectively complement automatic computation with human validation.
7. How to minimize involvement of users when turning matches into mapping.
8. Human readable explanations for matches.
9. Improving the mapping process through semi-automatic machine learning.
10. Integration of domain knowledge into alignment techniques.
11. Learning what metrics to choose in which scenario.
12. Precision and Recall of automatic methods.
13. Scalability and parallelization of the matching.

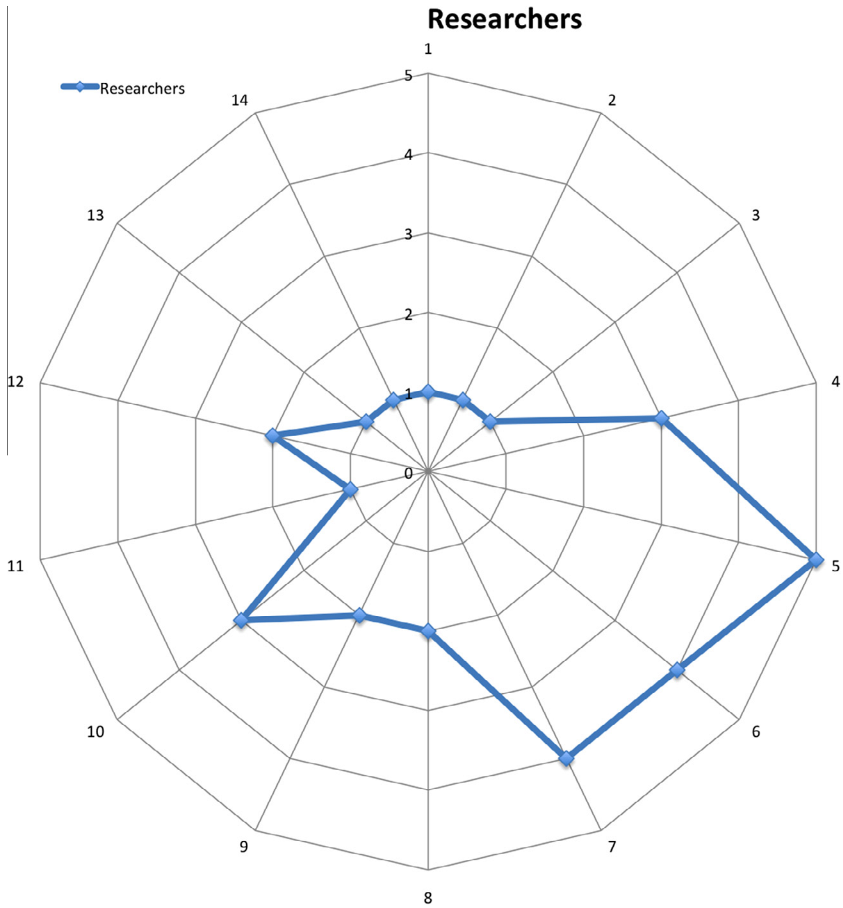

Fig. 10. Number of researchers in relation with the number of years working in the field.

14. Semantic mapping.

The answers provided by the practitioners for this question point out challenges that are inline with those highlighted by Euzenat and Shvaiko in Shvaiko and Euzenat (2013) and Euzenat and Shvaiko (2013).

Table 7 presents a comparison of those challenges outlined by Euzenat and Shvaiko and those mentioned by respondents to our survey. As this table states, most of the challenges issued by practitioners have been also considered in those by Euzenat and Shvaiko, however there are certain mismatches worth noticing.

As previously stated, most researchers mainly agree on 3 challenges, identified in Table 7 with '$*$', however, just one of these can be classified into the categories by Euzenat and Shvaiko. It is worth noticing that one of this challenges is the application of automatically created mappings to practical applications, which supports our working hypothesis to start this survey, that the application of ontology matching techniques in real-life projects is still a field to be further developed.

Some practitioners, in addition to pointing out the challenges, also used the answer to this question to mention certain situations that they consider a mistake, as the fact that most approaches to ontology matching focus on lexicographic and structural information while language is more complex than that and hence achieving a perfect precision and recall is impossible in real life applications. Other aspect they complained about was benchmarks habitually used to test the matching systems (OAEI benchmarks). They claim that even if they are really useful, their main drawback is that there are yet too many artificial datasets and tasks in it. Other practitioners took their remarks a step forward claiming that science culture does not reward creating and maintaining one tool and instead everyone creates a prototype for a paper and then abandons it.

Finally, regarding the fields where ontology matching could also be applied we have obtain two types of answers. Some practitioners gave a fuzzy answer mentioning that matching techniques could be used *practically anywhere where is no standard for information exchange and where the domains are open to adopt ontology approaches* or in broad sense in *any information related field*.

On the contrary, others actually mentioned fields to apply these techniques, such as: *bioinformatics, information systems, e-commerce, web services, intrusion detection systems, cultural heritage, library science, government, education, banking, personal and social data management, law, etc.* Most agree that the fact that in these fields ontologies and ontology matching techniques are not already in use is due to a lack of information regarding the potential benefits.

7. Limitations of the Survey

There are, of course, limitations to this survey, the foremost being the sampling size and the population. Although we feel that our 33 final responses offered a wide variety of useful remarks and points of view, it is true that the sample is still quite small and hence our analysis may be biased. Besides, in an effort to prevent the questions from influencing the answers and to obtain as much information as possible, we have defined the questionnaire with 8 open-ended questions. This fact, possibly together with the way some questions were posed, led us to obtaining answers that,

Table 7
Comparison of future challenges.

Challenges identified by Euzenat & Shvaiko	Challenges mentioned by practitioners
Large-Scale and Efficient Matching	Automated acquisition of reference alignment for evaluating large scale matching systems Creating large datasets to asses matching algorithms Scalability and parallelization of the matching ∗ Correctly align large ontologies
Matching with Background Knowledge	*Integration of domain knowledge into alignment techniques*
Matcher Selection, Combination and Tuning	Develop high quality and fast intelligent combinations of string-based and new semantic-similarity measures Learning what metrics to choose in which scenario
User Involvement	How to effectively complement automatic computation with human validation How to minimize involvement of users when turning matches into mapping
Explanation of Matching Results	Human readable explanations for matches
Uncertainty in Ontology Matching	–
Alignment Management	–
Other challenges that do not fit in previous categories	Improving the mapping process through semi-automatic machine learning Precision and Recall of automatic methods Semantic mapping Define good tools that are easy to use for non-experts Holistic ontology matching ∗ Automatically discover complex relations, instead of 1:1 ∗ Focus on applying automatically created mappings to practical applications

however interesting, did not exactly match what we expected from them. Also, the participants targeted were obtained from the participants at the OAEI contests, most of which are academically oriented, therefore our survey may be biased towards academical researchers rather than a balance between academical and industrial researchers. Finally, this survey was the answer to some concerns that arose while conducting the literature review, and we consider the results here as a first analysis. Our intention is to revisit these answers looking for deeper connections between the answers, to address questions such as: *Is there any relation between how long a researcher has been working in a subject and the amount of publications?*, *Which type of researchers are more prone to quitting?*, etc.

8. Conclusions

In this paper, we have achieved a twofold goal. Initially we performed a literature review of the ontology matching field, whose results led to the definition and development of the survey lately conducted.

To address the task of performing a literature review of the ontology matching field, we have defined a classification framework which helped in structuring our review by providing a comprehensive model to sort the different types of publications. This review was based on an online search of ontology matching related papers from 2003 to the first semester of 2013. The initial amount of articles obtained, over 1600, was reduced by filtering them according to their topics, keywords, abstracts and content.

With the articles left after the several trimming iterations, we have initially performed a statistical evaluation and analysis. Later, we have sorted the articles following the framework and then we have analyzed each one of the categories in the framework, evaluating the different types of articles and topics treated.

While performing this deeper analysis of the articles and their topics, some concerns arose regarding the actual research interests of the practitioners as we detected a high amount of papers related to theoretical solutions and approaches while the number of applied ones was significantly lower. The approach chosen to clarify these concerns was to ask openly to the research community, by means of a practitioner-oriented survey.

The purpose of such survey was to gain knowledge about the current state of the ontology matching field and the application of such techniques to real-life environments. We have noticed that most researchers share the same concerns about the practical application of the ontology matching techniques, and the problem of having too many theoretical solutions but few applied ones. However, due to the nature of the survey, with open-ended questions, there is more information that we have not reflected in this work and which we plan on analyzing and exploiting in the future.

By means of this work we have provided a general overview of the ontology matching field in the last decade. It can be used as a starting point for new practitioners to get a general idea but also, to help in deciding on research lines, hopefully by tackling some of the challenges highlighted in the survey.

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