Addressing the Lack of Direct Translation Resources for Cross-Language Retrieval

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ABSTRACT
Most cross language information retrieval research concentrates on language pairs for which direct, rich, and often multiple translation resources already exist. However, for most language pairs, translation via an intermediate language is necessary. Two distinct methods for dealing with the additional ambiguity introduced by the extra translation step have been proposed and individually, shown to improve retrieval effectiveness. Two previous works indicated that in combination, the methods were ineffective. This paper provides strong empirical evidence that the methods can be combined to produce consistent and often significant improvements in retrieval effectiveness. The improvement is shown across a number of different intermediate languages and test collections.

Categories and Subject Descriptors
H.3.3 [Information Search and Retrieval]: Query formulation, Search process.

General Terms
Algorithms, Measurement, Performance, Experimentation

Keywords
Cross-language information retrieval, cross-lingual, transitive translation, pivot language, structured queries.

1. INTRODUCTION
Transitive cross language retrieval is cross language information retrieval (CLIR) where there is no direct translation resource between the query (*source*) language and the document (*target*) language. In such cases, an intermediate language known as a pivot is used to provide a translation path from source to target. If it is necessary to use a pivot approach to CLIR, it can be assumed that the number and quality of translation resources available will be limited and that the primary problem to be solved will be the large translation ambiguity of the query after being translated twice. Two approaches have been applied to transitive retrieval to deal with ambiguity: use of *query structuring* to contain the ambiguity; and use of *triangulation* to eliminate some of it.

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Dictionaries typically contain multiple translation equivalents for each word. For example, translations of a 3-word query, s_1 s_2 s_3, could yield 3, 7, and 1 translation equivalents for query words s_1, s_2, and s_3, respectively. Without query structuring, the resulting translation effectively gives s_2 7 times the influence of s_3 in the target language query (and 2.3 times of s_1). Studies show that query structuring is an effective and straightforward means for reducing the effects of translation ambiguity for a wide variety of cross-language translation methods [1, 2, 5, 6, 11, 12, 14]. The most common approach used for query structuring has been the INQUERY synonym operator (#syn), introduced independently by [2, 12]. The synonym operator is used to treat all occurrences of the translation equivalents for a particular word as an instance of one *pseudo-word*. In this approach, term frequency statistics of the pseudo-word, are generated by combining the term frequency statistics of the translation equivalents. Consequently, important words (those with greater discrimination power) are given more weight and less important words (e.g. rare words) are given less weight. Moreover, structuring normalizes for the variation in the number of translation equivalents across query words. Ballesteros and Croft applied structuring to simple dictionary translations augmented by statistically based disambiguation techniques such as query expansion before or after query translation. Their work showed that improvements in cross-language retrieval effectiveness were due largely to query structuring. These results are consistent with the query structuring study done by Pirkola. In the case of transitive translation, Ballesteros [1] showed that adding query structure to transitive translations yielded significant improvements in retrieval effectiveness.

Gollins and Sanderson described an alternative approach they called *triangulated transitive translation* that produced pivot based CLIR roughly as effective as bilingual [5]. The method assumed the presence of two pivot languages. The following example (take from Gollins and Sanderson) assumes German queries, English documents, and Spanish & Dutch pivot languages:

"…if translating a German query word "fisch", a Spanish translation dictionary suggests two terms "pez, pescado" and the Dutch gives "vis". Taking each of these in turn, translating the Spanish terms to English gives "pitch, fish, tar, food fish", while Dutch to English gives "pisces the fishes, pisces, fish". Each of the transitive translations introduced much translation error

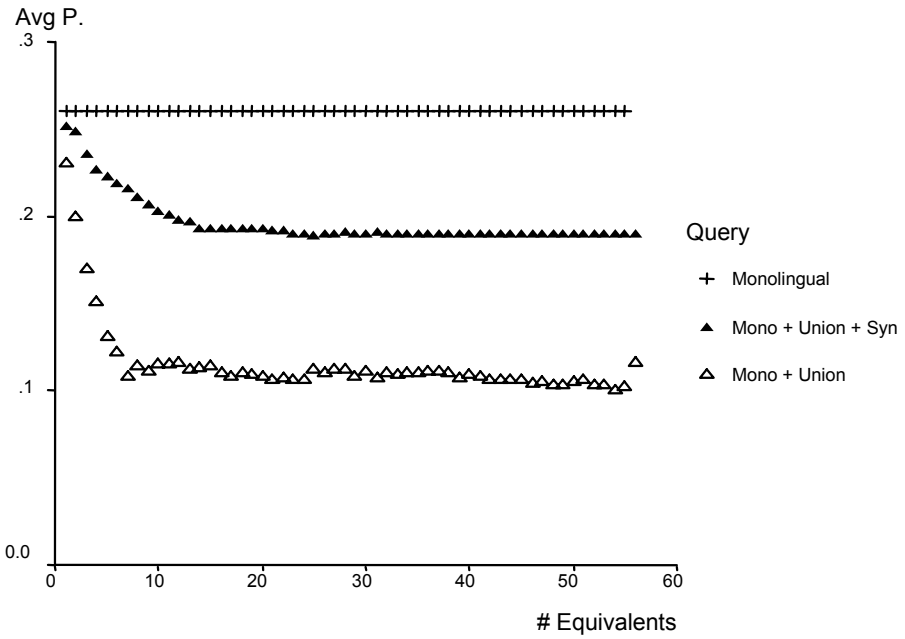

Figure 1 Effectiveness of Structuring as a Function of Translation Ambiguity and Translation recall.

largely due to word sense ambiguity. If we take the term that is in common from the two transitive translations, we have "fish", a good unambiguous translation of the original German word."

Note the triangulation is only eliminating any ambiguity introduced by the pivot translation. The ambiguity of the original query words remain, which Gollins attempted to contain using query structuring. However, he failed to show any improvement in effectiveness over simple triangulation. In more recent work Lehtokangas et al [8] compared unstructured versus structured bilingual, transitive, and triangulated translations of German, Swedish, and Finnish queries. Their conclusions were that structured queries were always better than unstructured. Moreover, they suggested that triangulation is harmful or unnecessary when structuring is employed, thus triangulation should only be employed when no structuring is possible, due for example to limitations of a retrieval system[1].

Given that triangulation leaves some ambiguity in the translation, it was judged somewhat surprising that the two past efforts had failed to show any benefit from merging the two approaches. Therefore a new more expansive study was conducted, and is reported here.

The next section, two, describes an initial experiment to illustrate the relationship between query structuring and ambiguity introduced by translation. This is followed by the set up for our main experiment, its methodology, test collections, and lexical resources. Section four presents our experimental results. Conclusions are given in Section five.

2. INITIAL EXPERIMENT

In order to better understand the relationship of query structuring to the ambiguity introduced when translating a query from source to target language across a pivot, a small experiment was conducted. Here, effectiveness of a retrieval system on the TREC-8 test collection was measured under three conditions.

- When correct translation is achieved – Monolingual.
- When the correct translation for each query word is augmented with one or more additional potentially incorrect translations taken from the query word's bilingual dictionary entry – Mono+Union[2].
- When the correct translation for each query word is augmented with one or more additional incorrect translations taken from the word's bilingual dictionary entry; and each set of query word translations are contained within a synonym operator – Mono+Union+Syn.

[1] A legitimate question to ask of triangulation, is although one can demonstrate its use experimentally, do situations occur in "real life" where triangulation is both possible and necessary? Gollins and Sanderson failed to answer this question in their paper; however, it has recently come to light that for both Latvian and Lithuanian, currently only electronic direct translation resources into English and one other language exist. In both cases the languages make excellent pivots. It may well be that other countries/languages will have similar properties of having a direct translation route into English along with the language of a nearby country or language associated with a strong cultural influence.

[2] By conducting this CLIR experiment across a pivot language, a large number of additional incorrect translations taken from dictionary entries for the query word could be added.

Figure 1 shows the relationship between the number of additional incorrect translations introduced, against the average precision of the retrieval system. As can be seen in the figure, as more translations are introduced, the effectiveness of both Mono+Union+Syn and Mono+Union drop compared to Monolingual, however, use of the synonym operator does ensure the drop in precision is much less than without the operator. What is perhaps surprising about the figure is to see how much the synonym operator is affected by additional ambiguity. The impression one might have gained from reading past work on use of syn in CLIR is that the operator does a particularly good job of managing incorrect translations. From this result computed on transitive CLIR, it is clear that if an additional means can be found to reduce ambiguity (such as triangulation) then synonym based CLIR will be improved.

3. EXPERIMENTAL METHODOLOGY AND RESOURCES

In order to test the benefits of combining triangulation and query structuring more completely than has been tried in past work, more than one test collection (which is more than was tested by Lehtokangas, et al) was used; and a more expansive translation resource was exploited than used by Gollins & Sanderson. We chose to use the twenty eight German and English TREC-8 CLIR queries in order to make direct comparisons to earlier work where possible. We ran additional experiments with the forty German and Finnish CLEF 2000 cross-language queries. We searched the corresponding English collections for these query sets, which are from the AP and LA Times collections, respectively. For translations, we employed the GlobalDix [16] multilingual dictionary. This is a commercially developed multilingual dictionary containing twenty one languages and as such should contain reasonably accurate translations. The languages used in our experiments and the number of entries within GlobalDix for each language are outlined in Table 1.

Table 1: Number of entries per language in GlobalDix

Language	# Entries
German	25,000
Finnish	26,000
French	29,000
Dutch	30,000
Swedish	36,000
English	44,000

3.1 Query Processing

The topics were each converted to three query types, the first composed of the title field alone (T), the second containing the title and description fields (TD), and the third composed of the title, description, and narrative fields (TDN). Stop phrases were removed to eliminate meaningless query structure such as "relevant documents contain". In order to match query terms with headwords in the dictionary, query words were first lemmatized: compound words were split into their component terms; inflected words were reduced to a canonical form more likely to be found as a dictionary headword. For the German queries, we employed a table driven stemmer based on CELEX [10] data, developed by Gollins [6]. Finnish query words were lemmatized via FINTWOL as described by Pirkola et al [11].

Stop word lists available on-line from the University of Neuchâtel [15] were used to remove non-function words from queries prior to translation. Query words were translated via simple replacement. In other words, each query term was replaced by all equivalents listed in the dictionary as possible translations for that term. Query terms not found in the dictionary were transferred un-translated to the target query. In this work, we chose to perform transitive translations from German/Finnish to English via French, Dutch, Finnish/German, and Swedish. Triangulated translations were generated by combining transitive translations of query terms as follows: the sets of translation equivalents generated from multiple transitive pathways, were joined by taking either their intersection or their union. In the case of intersection, if no equivalents were common to each transitive pathway in the merge, the un-translated query term was passed to the target query. In the following experiments, we created triangulated translations from all possible pairs of pivot paths and from a combination of all four pivot paths (Tri-4). The Wilcoxon Signed Ranks test was used for all significance testing.

All retrieval experiments were performed via the INQUERY retrieval system developed at the University of Massachusetts [4]. Query structuring was performed by wrapping the INQUERY synonym operator (#syn) around all translation equivalents associated with an original query term.

4. BASIC EXPERIMENTS

Tables 2, 3, and 4 present the results of our main experiments. Significant results at $p \leq 0.05$ are marked by "*". Baseline experiments were run on transitive and triangulated translations of German and Finnish queries. We compared retrieval effectiveness against monolingual queries and bilingual translations of cross-language queries. Bilingual translations were generated by direct translation from the source to the target language.

4.1 Query Length

In the TREC-8 collection for short queries (T), triangulated union (Union) typically performs worse than transitive translation (Trans) and both are less effective than bilingual. Triangulated intersection (Intersect in the tables) is more effective than either transitive or Union. Furthermore, Intersection is as effective as or more effective than Bilingual, although the results are not significant. However as the queries get longer (TD, TDN), effectiveness of transitive queries drops relative to Bilingual, reducing the gap between Union and transitive. Intersection continues to be as effective as or more effective than Bilingual, significantly so for Intersection queries that are combinations of French and Swedish or Dutch and Swedish pivot paths. Translations of the CLEF queries behave similarly. However, there is little change in the effectiveness of transitive queries relative to bilingual for the TD or TDN CLEF Finnish queries, and the intersection queries are rarely more effective than bilingual.

Triangulated intersection is always more effective than triangulated union, presumably because the level of translation ambiguity is lower (roughly two equivalents per term versus fifteen). For union, approximately 25% of terms was undefined for both TREC and CLEF queries; for intersection, 30–35% for TREC and 34–43% for CLEF. There were no queries in which zero query terms were translated.

Table 2: Effect of Synonym Operator on TREC-8 T, TD, & TDN Queries

			T			TD			TDN		
			¬Syn	Syn	%Chg	¬Syn	Syn	%Chg	¬Syn	Syn	%Chg
Bilingual (German-English)			0.09	0.11	*19.58*	0.10	0.13	*30.82*[*]	0.11	0.14	*36.38*[*]
Trans	Fi – Finnish		0.08	0.11	*32.21*	0.08	0.12	*57.30*[*]	0.10	0.13	*26.23*[*]
	Fr – French		0.08	0.11	*25.89*	0.05	0.11	*121.22*[*]	0.08	0.13	*71.18*[*]
	Nl – Dutch		0.07	0.10	*49.06*	0.07	0.12	*75.19*[*]	0.08	0.12	*64.43*[*]
	Sv - Swedish		0.08	0.11	*27.13*	0.07	0.12	*72.51*[*]	0.07	0.13	*88.58*[*]
Tri	Fi-Sv	Union	0.07	0.11	*43.06*	0.07	0.11	*51.57*[*]	0.09	0.12	*42.92*[*]
		Intersect	0.10	0.11	*7.83*	0.11	0.13	*18.15*[*]	0.13	0.14	*12.97*[*]
	Fr-Nl	Union	0.07	0.10	*49.20*	0.07	0.11	*59.75*	0.09	0.13	*52.23*[*]
		Intersect	0.10	0.11	*12.42*	0.11	0.12	*11.65*[*]	0.11	0.13	*10.87*[*]
	Fi-Fr	Union	0.08	0.11	*29.62*	0.08	0.11	*37.97*	0.09	0.13	*33.61*[*]
		Intersect	0.10	0.12	*16.35*[*]	0.11	0.12	*9.07*	0.12	0.13	*6.52*
	Fi-Nl	Union	0.07	0.10	*53.72*	0.07	0.11	*55.28*	0.09	0.13	*28.08*
		Intersect	0.09	0.11	*19.20*[*]	0.10	0.13	*32.22*[*]	0.12	0.14	*18.98*[*]
	Fr-Sv	Union	0.08	0.11	*28.21*	0.07	0.10	*43.18*[*]	0.08	0.11	*41.01*[*]
		Intersect	0.10	0.11	*8.98*	0.11	0.12	*7.82*	0.12	0.13	*7.48*
	Nl-Sv	Union	0.07	0.10	*53.51*	0.08	0.10	*52.72*	0.08	0.11	*38.25*
		Intersect	0.10	0.11	*7.14*	0.11	0.14	*26.74*[*]	0.12	0.14	*17.64*[*]
Tri-4		Union	0.06	0.10	*77.42*	0.05	0.09	*93.29*[*]	0.06	0.10	*67.12*
		Intersect	0.10	0.12	*21.52*	0.11	0.12	*12.40*[*]	0.12	0.13	*7.88*[*]
		Flex. Int.	0.10	0.11	*11.04*	0.11	0.13	*25.10*			

4.2 Synonym

With few exceptions, query structuring via the synonym operator yields an increase in average precision. When comparing specific translation paths, increases in effectiveness are much greater when applied to those translations generated by taking the union. This makes sense since triangulated unions are more ambiguous than triangulated intersections. Seven out of 135 runs result in a small drop in average precision (none of them significant) and five of them are the result of applying the synonym operator to translation generated via path intersection. Fifty three of the structured query sets are significantly better than their unstructured counterparts and twelve of these were structured intersections.

We find that application of the synonym operator to transitive translations yields improvements of 8%–121% in average precision. Union plus synonym of two triangulation paths yields improvements of 7%–60%, while intersection plus synonym of two paths yields differences of between -5%–29%. On the TREC-8 collection, ten of the eighteen language/query pairs tested produced significant improvements for Syn plus Intersection over Intersection alone. On the CLEF collections (those used in [8]), significance of positive (or negative) changes were only once observed, however, use of Syn on Intersection rarely cause a drop in effectiveness (five out of twenty four). Triangulation with all four transitive paths results in improvements of 57%–93% and 1%–22% for combinations via union and intersection, respectively[3]. It would appear that there is good evidence that on the TREC collections in particular use of both intersection-based triangulation and the synonym operator produces the best CLIR effectiveness.

Translations of the German TREC-8 queries that yielded the highest average precision were structured, triangulated intersections of two transitive paths involving Finnish-Swedish, Finnish-Dutch, or Dutch-Swedish. For the CLEF German queries, the highest average precision was generated by structured, triangulated intersections of Dutch-Swedish or French-Swedish. This was consistent across both the TD and TDN queries. The best translation paths for all of these query sets are similar in that they employed Swedish and Dutch as pivots, but differed in that the best TREC-8 translations also employed Finnish as a pivot while the best CLEF German translations employed French as a pivot. Although these translations yield higher average precision than bilingual translation, only the TREC-8 translations yield statistically significant differences.

The best translations of the CLEF Finnish queries were combinations of German, Dutch, and Swedish. This is consistent for both the TD and TDN queries. However, translations of the TD queries yielding the highest average precision were generated by structured, triangulated intersections of German-Dutch and triangulated union of Dutch-Swedish. Structured, triangulated intersections of German-Dutch or German-Swedish, and structured, triangulated union of Dutch-Swedish generated the

[3] The motivation for employing transitive and triangulated translations is that they provide mappings between source and target languages when no bilingual lexical resource is available. For this reason, we compare only to bilingual translation and not to bilingual translations structured via synonym. The latter generally yields higher average precision than either transitive with Syn or triangulated with Syn, although rarely is the difference statistically significant.

Table 3: Effect of Synonym Operator on CLEF TD & TDN German Queries

			TD			TDN		
			¬Syn	Syn	%Chg	¬Syn	Syn	%Chg
Bilingual (German-English)			0.12	0.15	*28.34*	0.14	0.17	*23.23*
Trans	Fi - Finnish		0.08	0.11	*31.92*	0.09	0.13	*47.24*
	Fr - French		0.09	0.12	*42.86*	0.08	0.16	*84.41**
	Nl - Dutch		0.10	0.14	*46.24**	0.13	0.17	*29.54**
	Sv - Swedish		0.12	0.14	*15.40**	0.13	0.17	*28.14*
Tri	Fi-Sv	Union	0.11	0.12	*7.91*	0.11	0.16	*52.45**
		Intersect	0.12	0.14	*16.65*	0.13	0.15	*11.86*
	Fr-Nl	Union	0.09	0.13	*52.96**	0.11	0.16	*55.78**
		Intersect	0.13	0.14	*5.97*	0.16	0.18	*10.81*
	Fi-Fr	Union	0.09	0.12	*38.85**	0.11	0.16	*40.24**
		Intersect	0.12	0.12	*-0.74*	0.13	0.14	*6.12*
	Fi-Nl	Union	0.09	0.12	*27.41*	0.12	0.15	*29.40**
		Intersect	0.12	0.14	*21.20*	0.12	0.14	*22.91*
	Fr-Sv	Union	0.10	0.12	*16.66*	0.11	0.15	*39.05**
		Intersect	0.16	0.16	*2.14*	0.18	0.18	*2.61*
	Nl-Sv	Union	0.11	0.13	*25.00**	0.11	0.17	*47.05**
		Intersect	0.14	0.16	*13.76*	0.16	0.18	*12.36*
Tri-4		Union	0.08	0.12	*56.77*	0.10	0.15	*58.76**
		Intersect	0.14	0.15	*2.08*	0.15	0.15	*1.44*

Table 4: Effect of Synonym Operator on CLEF TD & TDN Finnish Queries

			TD			TDN		
			¬Syn	Syn	%Chg	¬Syn	Syn	%Chg
Bilingual (Finnish-English)			0.11	0.10	*-7.09*	0.12	0.12	*-0.69*
Trans	De - German		0.10	0.12	*18.55**	0.11	0.13	*22.50**
	Fr - French		0.08	0.10	*19.50*	0.11	0.12	*10.25*
	Nl - Dutch		0.10	0.13	*27.36**	0.11	0.14	*24.32**
	Sv - Swedish		0.09	0.10	*8.72*	0.10	0.12	*16.37*
Tri	De-Nl	Union	0.09	0.12	*38.43**	0.09	0.14	*56.63**
		Intersect	0.10	0.13	*28.57**	0.12	0.14	*15.78*
	De-Fr	Union	0.08	0.09	*12.48*	0.09	0.12	*37.90*
		Intersect	0.11	0.11	*3.30*	0.11	0.13	*14.30**
	De-Sv	Union	0.07	0.10	*38.27*	0.09	0.13	*47.65*
		Intersect	0.11	0.12	*5.30*	0.12	0.14	*18.11*
	Fr-Nl	Union	0.10	0.12	*19.48**	0.10	0.13	*22.72**
		Intersect	0.11	0.11	*-8.38*	0.13	0.12	*-5.34*
	Fr-Sv	Union	0.09	0.10	*6.31*	0.11	0.12	*6.87*
		Intersect	0.11	0.11	*-1.61*	0.12	0.12	*-0.13*
	Nl-Sv	Union	0.09	0.12	*36.60*	0.10	0.13	*32.52*
		Intersect	0.12	0.12	*2.54*	0.12	0.13	*10.52*
Tri-4		Union	0.07	0.11	*61.78*	0.07	0.12	*56.69**
		Intersect	0.10	0.11	*4.55*	0.11	0.12	*5.54*

translations of the TDN queries yielding the highest average precision. None of these yielded statistically significant differences when compared to bilingual translation. It is unclear why in these cases, the structured union of the above paths were more effective than their respective structured intersections. This may be due in part to a difference in translation recall, the number of original monolingual query terms recovered by translation. Roughly 50% of the monolingual query terms were recovered via union, while only 35% were recovered via intersection.

5. FINAL EXPERIMENT

From the experimental results described in Section 4, there is evidence that use of intersection based triangulation along with the synonym operator produces an effective form of cross

language retrieval. It is to be presumed that intersection is selecting the correct pivot translation most of the time, thereby causing an improvement. However, if no intersection is found across the translations of two pivot languages, the query word in its original source language is used in the query. Chances are high that the word in this form will not match on any target language document text. Intersection as it was implemented and used in Sections 3 & 4 introduced problems of effectively dropping "non-intersecting" query words as well as providing the advantages of translation selection. Despite the disadvantage, however, intersection was shown to work positively with Syn.

A final experiment was conducted to try to remove the disadvantage of intersection. Here, if no intersection was found, all the target language words which were shared by at least two paths resulting from a pivot language translation were included in the query. Due to time restrictions, the experiment was only conducted on one configuration of pivot and collection. The result is shown at the bottom of Table 2, so called "flexible intersect". It can be seen that such a change to the implementation of intersection has a mixed effect: flexible intersection with synonym improves over union for both T and TD queries. For T queries, flexible intersection is slightly worse than intersection, for TD, it is slightly better: improving effectiveness by 25.10% compared to 12.40% from simple intersection on the same pivots. It would be premature to draw conclusions from this single result.

6. CONCLUSIONS AND FUTURE WORK

In this paper, we show that query structuring improves retrieval effectiveness for transitive and triangulated retrieval. Through a more extensive study (in terms of numbers of test collections and language pairs examined) than was conducted before, we show that contrary to previous work, a combination of both query structuring and an intersected triangulation of multiple pivot languages produces the best retrieval effectiveness. The results from a final test on a more flexible form of intersection hints at possible benefits to come from the merging of these two different approaches.

As part of future work, exploring means of incorporating weighting information (derived from triangulation data) into the elements of a structured query (similar to that recently reported by Darwish and Oard, [17]) will be explored.

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8. REFERENCES

[1] Ballesteros, L. Cross-Language Retrieval via Transitive Translation. Advances in Information Retrieval: Recent Research from the CIIR, pp. 203-234. W. Bruce Croft, Ed. Kluwer Academic Publishers, 2000.

[2] Ballesteros, L. and Croft, W.B. Resolving Ambiguity for Cross-Language Retrieval. Proceedings of the 21st ACM SIGIR Conference on Research and Development in Information Retrieval, pp. 64-71, August 1998.

[3] Ballesteros, L. and Croft, W.B. Phrasal Translation and Query Expansion Techniques for Cross-Language Information Retrieval. Proceedings of the 20th ACM SIGIR Conference on Research and Development in Information Retrieval, pp. 84-91, July 1997.

[4] Broglio, J., Callan, J., and Croft, W.B. Inquery system overview. In Proceedings of the TIPSTER Text Program (Phase I), pp 47-67, 1994.

[5] Gollins, T and Sanderson, M., Improving Cross Language Retrieval with Triangulated Translation. In Proceedings of the 24th annual international ACM SIGIR conference on research and development in information retrieval, pp 90-95, 2001

[6] Gollins, T., Dictionary Based Transitive Cross-Language Information Retrieval Using Lexical Triangulation. MSc Dissertation, University of Sheffield. 2000.

[7] Lehtokangas, R. and Airio, E., Translation via a Pivot Language Challenges Direct Translation in CLIR. Working Notes of the SIGIR 2002 Workshop on Cross-language Information Retrieval, pp 19-24.

[8] Lehtokangas, R. and Airio, E., and Järvelin, K. Transitive dictionary translation challenges direct dictionary translation in CLIR. University of Tampere Technical Report, 2003. http://www.info.uta.fi/tutkimus/fire/archive/RL_200503.pdf.

[9] Peters, C., Cross-Language Information Retrieval and Evaluation, Workshop of Cross-Language Evaluation Forum, CLEF 2000, Lisbon, Portugal, September 21-22, 2000, Revised Papers. Editor: Carol Peters.

[10] Piepenbrock, R. CELEX, The Dutch Center for Lexical Information, CELEX, 2000. http://www.kun.nl/celex/.

[11] Pirkola, A., Hedlund, T., Keskusalo, H., and Järvelin, K., Cross-language Information Retrieval Problems, Methods, and Research Findings. In Information Retrieval, vol. 4, 2001. pp. 209-230.

[12] Pirkola, A. The effects of query structure and dictionary setups in dictionary-based cross-language information retrieval. In Proceedings of the 21st ACM SIGIR Conference on Research and Development in Information Retrieval, pp. 55-63, August 1998

[13] Voorhees, E.M., and Harman, D.K., NIST Special Publication 500-246: The Eighth Text REtrieval Conference (TREC-8), 1999. Editors: E. M. Voorhees and D. K. Harman

[14] Sperer, R. and Oard, D.W. Structured Translation for Cross-Language Information Retrieval. In Proceedings of the 23rd annual international ACM SIGIR conference on research and development in information retrieval, pp 120-127, 2000.

[15] University of Neuchâtel multilingual retrieval page. http://www.unine.ch/info/clef/

[16] Kielikone multilingual dictionaries. www.kielikone.fi.

[17] Darwish, K. and Oard, D.W. Probabilistic structured query methods. In Proceedings of the 26th ACM SIGIR Conference on Research and Development in Information Retrieval, pp. 338-344, July 2003.