Cross-Lingual Image Search on the Web

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Limitations to Monolingual Image Search

1. Limited Resource Languages
   Slovenian query ‘grenivka’ (grapefruit)
   Results: only 9 images of grapefruit
Limitations to Monolingual Image Search

1. **Limited Resource Languages**
   
   Slovenian query ‘grenivka’ (grapefruit)

2. **Cross-Cultural Images**
   
   Search for images of ‘food’ in different cultures
Zulu query: ‘ukudla’ (food)
Limitations to Monolingual Image Search

1. Limited Resource Languages
   Slovenian query ‘grenivka’ (grapefruit)

2. Cross-Cultural Images
   Search for images of ‘food’ in different cultures

3. Cross-lingual homonyms
   Hungarian word for tooth is ‘fog’
   Results: misty weather, not teeth
Limitations to Monolingual Image Search

1. Limited Resource Languages
   Slovenian query ‘grenivka’ (grapefruit)

2. Cross-Cultural Images
   Search for images of ‘food’ in different cultures

3. Cross-lingual homonyms
   Search for images with Hungarian word for tooth

4. Word Sense Ambiguity
   Search in English for spring (flexible coil)
English query: ‘spring’
Solution: PanImages

- PanImages builds a translation graph from several dictionaries
- User specifies a language and a query term
- PanImages presents possible translations
- User selects one or more translation
- PanImages sends translated query to Google Images
Select from 50 source languages

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Cross Lingual Image Search

Search Google Images in 50 languages using automatic query translation

1. Choose the language to translate from
2. Type in a word in that language
3. Press 'Translate'
4. Finally, click on a translation to view images.


Language: Slovenian [slovenščina]

Search idea: Choose 'English', type in 'babies', look at babies from around the world.
PanImages for Slovenian ‘grenivka’

Usage Instructions and Tips

Language: Slovenian [slovenščina] grenivka

Search idea: Choose ‘English’, type in ‘baby’ and press ‘Translate’ to look at babies from another language.

Select a word sense:

Sense 1 of 1: Check First 32 Uncheck all Languages with many images:

- English
  - grapefruit
- French [français]
- pamplemousse
- pomeio

All other available languages:

- Alabama
- Dutch [Nederlands]
- Finnish [suomi]
- German [Deutsch]

over 40,000 images for ‘grapefruit’ or ‘pamplemousse’
Search: English ‘Spring’

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Cross Lingual Image Search

Search Google Images in 50 languages using automatic query translation

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Language: English

Search idea: Choose 'English', type in 'baby' and press 'Translate'.

spring
spring bolt
spring onion
spring roll
spring tab
Senses for ‘Spring’

Different word senses found in the translation graph:

- water source (107 translations)
- a season (62 translations)
- to jump or leap (58 translations)
- device made of flexible material (38 translations)
- to start to exist (12 translations)
- rope on a boat (2 translations)
- --- (73 translations)
- --- (35 translations)
- --- (13 translations)

Languages with many images:
Select the Intended Sense of 'spring'

Select a word sense:
- water source (107 translations)
- a season (62 translations)
- to jump or leap (58 translations)
- device made of flexible material (38 translations)
- to start to exist (12 translations)
- rope on a boat (2 translations)

--- (73 translations)
--- (35 translations)
--- (13 translations)
--- (6 translations)
--- (2 translations)

Sense 4 of 11: device made of flexible material

Languages with many images:

| Language          | | spring |
|-------------------|----------|
| English           |          |
| French [français] | □ ressort |

All other available languages:

- Belarusian
- Breton [brezhoneg]
- Chinese [中文]
- Czech [čeština]
Translated query for ‘spring’

French ‘ressort’ is unambiguous
Outline of Talk

• Overview of PanImages

• Building a translation graph
  – Merging entries from multiple dictionaries
  – Computing translation probabilities

• Experimental Results

• Conclusions
PanImages Architecture

dictionaries

PanImages compiler

translation graph

1. query

2. translations

PanImages query processor

translated query

3. select translation

user

images

Google Image Search
Input from Machine Readable Dictionaries

• Multilingual dictionaries:
  – Each entry has translations in multiple languages
  – Distinguishes different senses of the word
  – “Wiktionaries” for 171 languages created by Web volunteers
    www.wiktionary.org
  – Esperanto dictionary purl.org/net/voko/revo

• Bilingual dictionaries:
  – Each entry has translations into a single language
  – May mix together different senses of the word
  – freedict.org has 64 open source dictionaries
Translation Graph

- Nodes in the graph are ordered pairs \((\text{word}, \text{language})\)
- Edges in the graph indicate translations between words
- Each edge is labeled with a word sense ID

Edges from ‘spring’ from an English dictionary
Merging Multilingual Dictionaries
(English Dictionary)
Merging Multilingual Dictionaries
(English and French Dictionaries)
Merging Multilingual Dictionaries
(English and French Dictionaries)
Adding Bilingual Dictionaries

from a Vietnamese-English dictionary

spring
English

xuân
Vietnamese

printemps
French

primavera
Spanish

udaherri
Basque

22
Adding Bilingual Dictionaries

- spring (English)
- primavera (Spanish)
- xuân (Vietnamese)
- printemps (French)
- udaherri (Basque)

from a Vietnamese-French dictionary
Inferring Word Sense Equivalence

- Compute $prob(s_i = s_j)$ where $s_i$ and $s_j$ are word senses
- **Case1:** $s_i$ and $s_j$ are each from
  - multilingual dictionaries
  - that distinguish word senses
- **Case2:** $s_i$ or $s_j$ are from either
  - bilingual dictionaries
  - or dictionaries that mix together word senses
Word Sense Equivalence

Multilingual dictionaries:

\[ \text{prob}(s_i = s_j) \] is proportional to the degree of overlap between \( \text{nodes}(s_i) \) and \( \text{nodes}(s_j) \), where \( \text{nodes}(s) \) is the set of nodes with edges labeled \( s \).

\[
\text{prob}(s_i = s_j) = \max \left( \frac{|\text{nodes}(s_i)| \cap |\text{nodes}(s_i)| + \alpha}{|\text{nodes}(s_i)| + \beta}, \frac{|\text{nodes}(s_i)| \cap |\text{nodes}(s_i)| + \alpha}{|\text{nodes}(s_j)| + \beta} \right)
\]
Word Sense Equivalence

Bilingual dictionaries (or not sense distinguished):

\[ \text{prob}(s_i = s_j = s_k \mid \exists \text{clique}(s_i, s_j, s_k)) \]

Estimate this probability empirically. (prob = 0.85)

\text{clique}(s_i, s_j, s_k) : a triangle from three dictionary entries
Computing Translation Probabilities

- Probability decreases each time the word sense ID changes.
- Probability increases with multiple distinct paths.
Computing Translation Probabilities

- CLISE can find translations that are not in any single source dictionary
- Translation probability decreases with each transition to a new word sense ID

\[
\text{path } P \text{ from } n_1 \text{ to } n_k
\]

\[
\text{pathp}(n_1, n_k, s, P) = \max_{i \in [1, |P|]} (\text{prob}(s = s_i)) \prod_{i \in [1, |P| - 1]} \text{prob}(s_i = s_{i+1})
\]
Probability from Multiple Paths

- Probability that $n_1$ is translated as $n_k$ in sense $s$ increases when there are multiple paths between $n_1$ and $n_k$

\[ \text{prob}(n_1, n_k, s) = 1 - \prod_{P \in \text{distinctP}} (1 - \text{pathp}(n_1, n_k, s, P)) \]
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Graph Statistics

- Translation graph from 17 dictionaries:
  - English Wiktionary: 19,500 words with translations
  - French Wiktionary: 12,700 words with translations
  - Esperanto dictionary: 23,000 words with translations
  - 14 bilingual dictionaries: average 90,000 words each

- Graph has:
  1.4 million words
  957 languages
  60 languages have over 1,000 words
Experiment 1: Translation paths in Graph

• Evaluate translations for language pairs:
  – English - Russian
  – English - Hebrew
  – Turkish - Russian

• Select random 1,000 English (Turkish) words from graph

• Compare number of words translated, precision
  – Baseline is Direct translation
  – Multilingual dictionaries vs. All dictionaries

  – Effect of path length
## Results of Experiment 1

<table>
<thead>
<tr>
<th></th>
<th>Direct (length = 1)</th>
<th>Multilingual (length &lt;= 2)</th>
<th>All Dictionaries (length &lt;= 2)</th>
<th>All Dictionaries (length &lt;= 4)</th>
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<tr>
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<td>words</td>
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<td>words</td>
<td>P</td>
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<tr>
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**Direct translations:**
- same sense ID in multilingual dictionary
- precision 0.92 due to parsing errors (inconsistent dictionary formats)
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Adding paths with 2 sense IDs between multilingual dictionaries:
- modest gain in number of words translated
- precision in mid 0.80’s
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Adding paths of length 2 from bilingual dictionaries:
- precision still above 0.80
- large gain in number of words translated
- biggest gain from adding Turkish bilingual dictionaries
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Adding paths with more than 2 sense IDs:
- only a small further gain in words translated
- sharp drop in precision
Experiment 2: Image Search

• 10 concepts with distinctive images:
  ant, clown, fig, lake, sky, train, eat, run, happy, tired

• 100 random non-English terms from translation graph
  – 10 terms for each concept

• Compare results of Google Image search
  – using non-English term as search query
  – using PanImages translation into English

• Metrics:
  – Number of results
  – Precision of first 15 pages of results (18 results per page)
For “33 minor languages” (Danish, Dutch, Greek, Lithuanian, …)
- Increases number of correct results by **75%** on first 270 results
- Increases average precision by **27%**
Future Work

• Increase precision of translation paths
  – Cleaner parsing of dictionaries
  – More accurate word sense equivalence probabilities

• PanImages Web page in user’s choice of language

• Word sense glosses in user’s language

• More dictionaries to increase coverage of graph
Conclusions

• PanImages: a fully-implemented cross-lingual image search system for the Web:  
  www.cs.washington.edu/research/panimages

• PanImages boosts recall and raises precision for minor language search queries

• We introduced the translation graph  
  – Combines multiple machine readable dictionaries  
  – Probabilistic word-sense merging across dictionaries  
  – Infers translations not found in any source dictionary
Thank you!