The PanLex Project

International Computer Science Institute, Berkeley, California, 27 January 02015

The goal of open-domain automatic translation of text among all human languages is ambitious, but what about the more limited goal of translating any lexeme into any language? Even this involves trillions of mappings, with quality loss when performed inferentially through intermediate languages. From 2006 to 2010, researchers at the University of Washington's Turing Center headed by Oren Etzioni combined digital dictionaries into a "translation graph" and achieved more efficient automatic inference of translations than with existing methods. Their graph, built mainly from Wiktionaries and Freelang and Freedict dictionaries, contained about 3 million lexemes. They discovered computationally practical sampling algorithms for inferring new translations without loss of precision.

Now sponsored by The Long Now Foundation in San Francisco and partnering with The Rosetta Project and the Internet Archive, the PanLex project is building and deploying this resource for research and development communities via an API, monthly database snapshots, and online applications. PanLex's database has now grown to contain 21 million lexemes, in about 10,000 languages and dialects, written in 60 scripts, with 1.2 billion attested pairwise translations. No longer a proof-of-concept project, it aspires to integrate all known lexical translations into a consistent data structure, supporting theoretical and applied research in language typology, semantic universals, machine translation, web search, text summarization, human-computer interaction, controlled languages, endangered-language revitalization, biolinguistic diversty, and other fields.

PanLex is open-source and employs Unicode, PostgreSQL, GNU/Linux, and other open-source standards and software. Its content curation is currently a small-team effort, but crowdsourced contributions are planned.

People

David Kamholz, lexical data specialist, received his linguistics Ph.D. from UC Berkeley in 2014. He has worked on computational lexicography and the historical linguistics of Austronesian languages. **Jonathan Pool**, project director, has a Ph.D. in political science from The University of Chicago. His research and teaching have focused on language politics and policy, and on language choice as a decision-theoretic problem. The PanLex team also includes research associate **Susan Colowick**, Rosetta Project director **Laura Welcher**, local volunteers, and occasional interns. The project's steering committee includes **Emily Bender** at the University of Washington and **Steven Bird** at the University of Melbourne. The project has a 19-member advisory committee.

The PanLex Project

http://panlex.org

(A project of The Long Now Foundation, San Francisco)

International Computer Science Institute
Berkeley, California
27 January 02015

The PanLex Project: Outline

- Problem
- Solution concept
- Concept evaluation (2006–2010)
- Open resource development (2010–)
- People, partners, publications

Problem

- Enable panlingual open-domain automatic translation
- Prioritize panlinguality

Solution concept

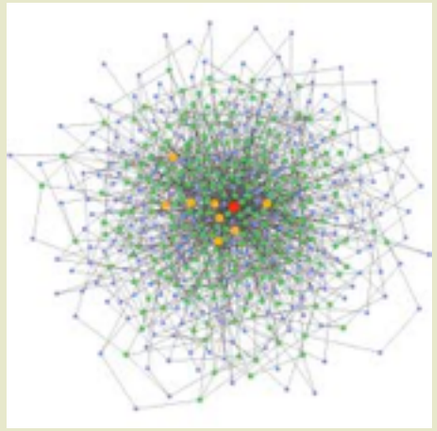
Reiter/Etzioni “Lexical Hypothesis”:

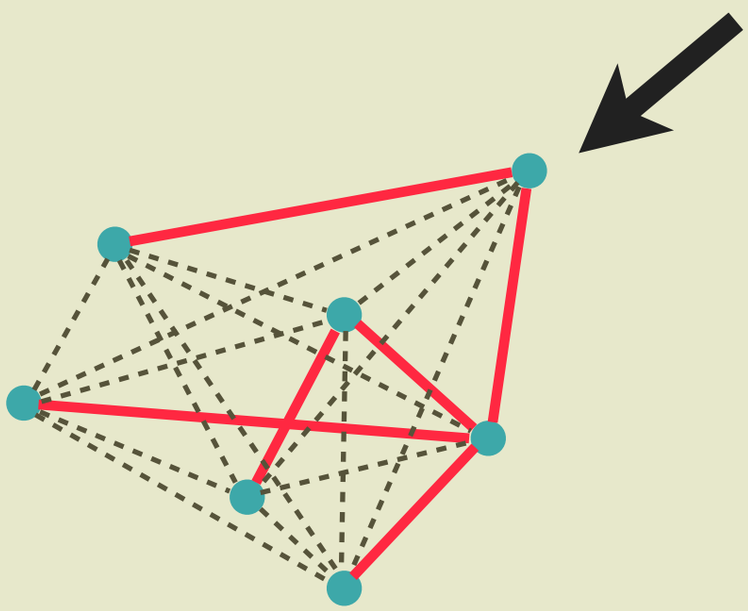
- Lexicons vs. grammars:
  - Lexeme data more:
    - Panlingually abundant
    - Tractable
  - Lexemic-only communication more useful
- Therefore, begin with a lexemic solution

Solution concept

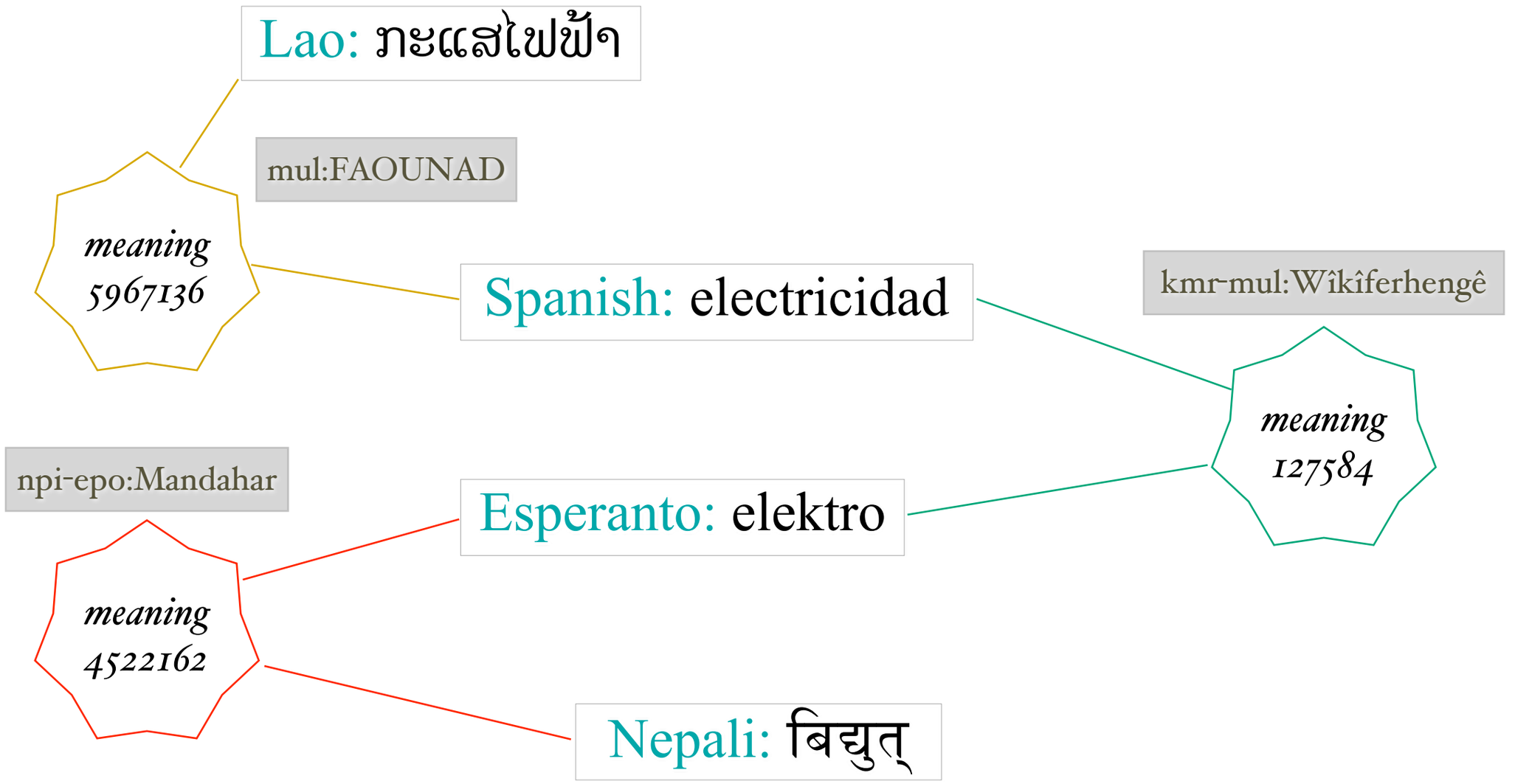
Reiter/Etzioni lexemic solution:

- Acquire lexeme translations from multiple sources
- Combine them into a *translation graph*
- Infer missing translations





Solution concept

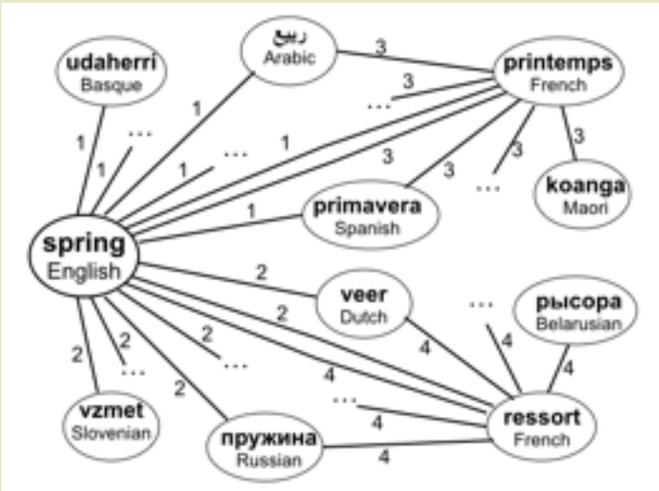


Concept evaluation

Prototype translation graph (University of Washington Turing Center):

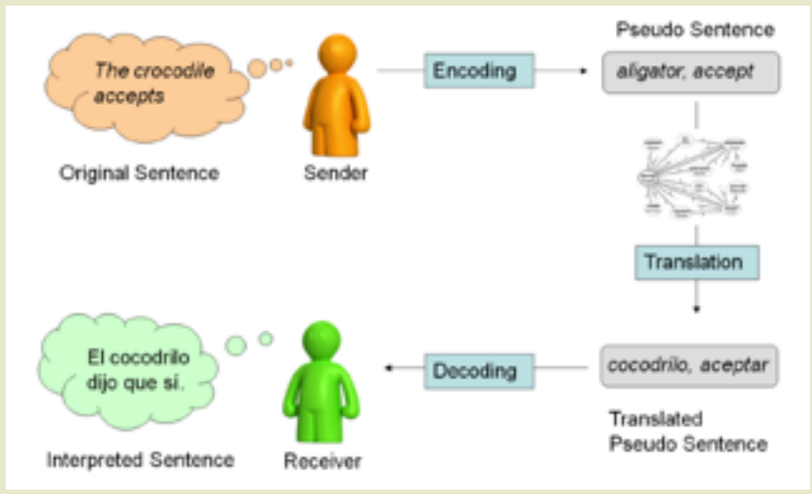
- 300–600 sources from Wiktionary, Freelang, Freedict, …
- 1–10 million lexemes (vertices)
- 2–60 million undirected pairwise translations (edges)

Concept evaluation



Lexical translation inference

Multilingual web search



Lexeme-only communication

Concept evaluation

Demonstration applications

Concept evaluation

Marcus Sammer, Kobi Reiter, Stephen Soderland, Katrin Kirchhoff, Oren Etzioni, "Ambiguity Reduction for Machine Translation: Human-Computer Collaboration", AMTA 2006.

Marcus Sammer, Stephen Soderland, "Building a Sense-Distinguished Multilingual Lexicon from Monolingual Corpora and Bilingual Lexicons", MT Summit 2007.

Oren Etzioni, Kobi Reiter, Stephen Soderland, Marcus Sammer, "Lexical Translation with Application to Image Search on the Web", MT Summit 2007.

Susan Colowick, "Multilingual Search with PanImages", *Multilingual* 2008.

Stephen Soderland, Christopher Lim, Mausam, Bo Qin, Oren Etzioni, Jonathan Pool, "Lemmatic Machine Translation", MT Summit 2009.

Mausam, Stephen Soderland, Oren Etzioni, Daniel S. Weld, Michael Skinner, Jeff Bilmes, "Compiling a Massive, Multilingual Dictionary via Probabilistic Inference", ACL-IJCNLP 2009.

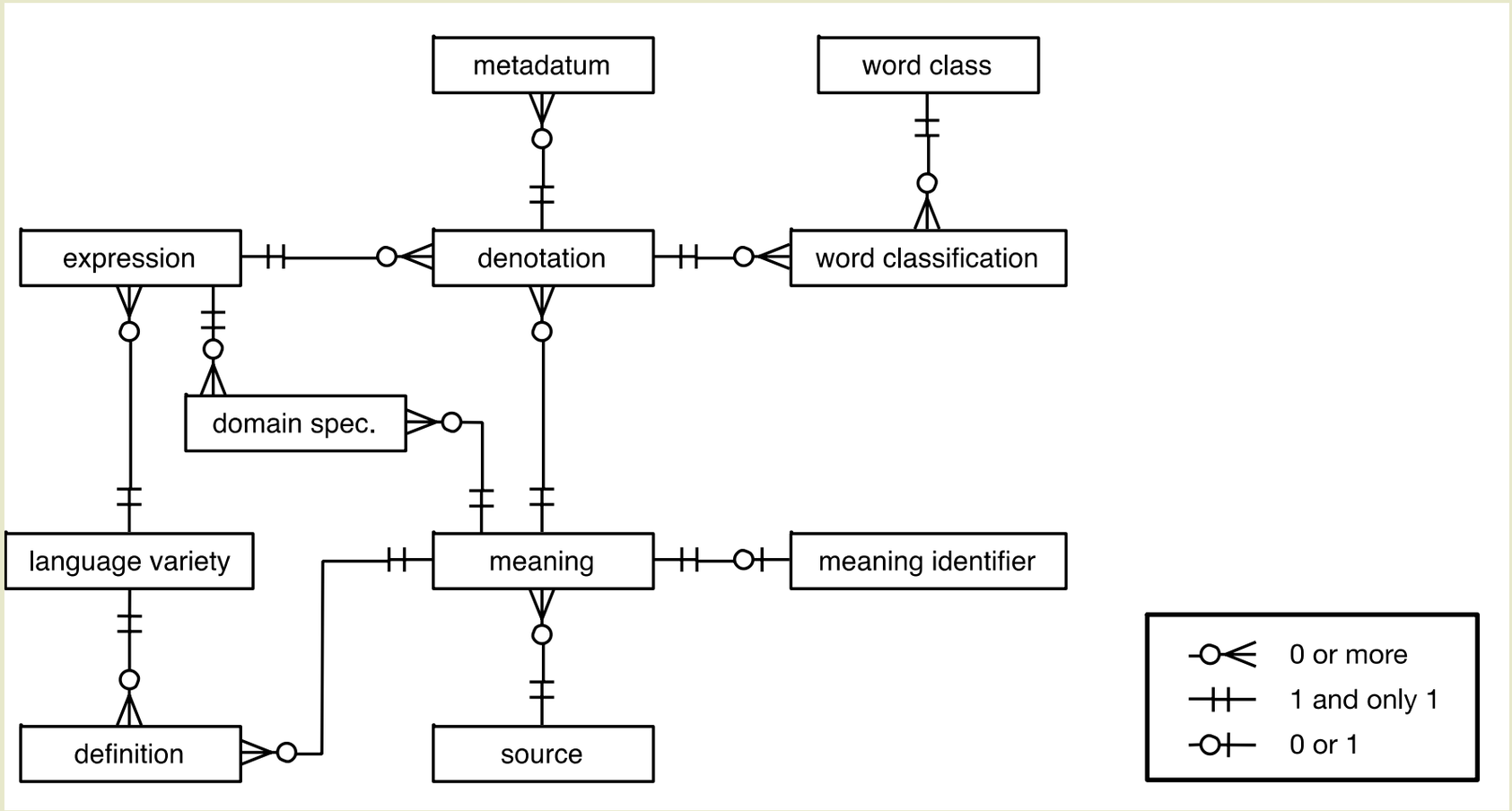
Janara Christensen, Mausam, Oren Etzioni, "A Rose is a Roos is a Ruusu: Querying Translations for Web Image Search", ACL-IJCNLP 2009.

Katherine Everitt, Christopher Lim, Oren Etzioni, Jonathan Pool, Susan Colowick, Stephen Soderland, "Evaluating Lemmatic Communication", *trans-kom* 2010.

Mausam, Stephen Soderland, Oren Etzioni, Daniel S. Weld, Kobi Reiter, Michael Skinner, Jeff Bilmes, "Panlingual Lexical Translation via Probabilistic Inference", *Artificial Intelligence* 2010.

Open resource development

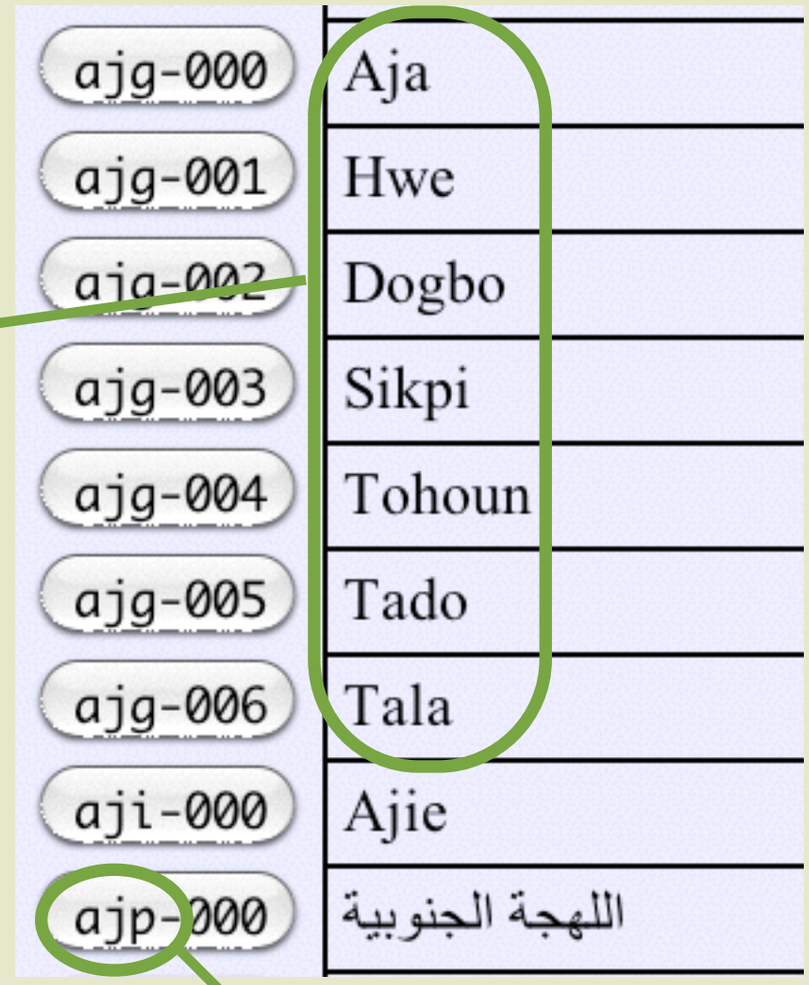
- Refined database schema (language *varieties*, domains, …)
- Open-source DB (PostgreSQL) and OS (GNU/Linux)

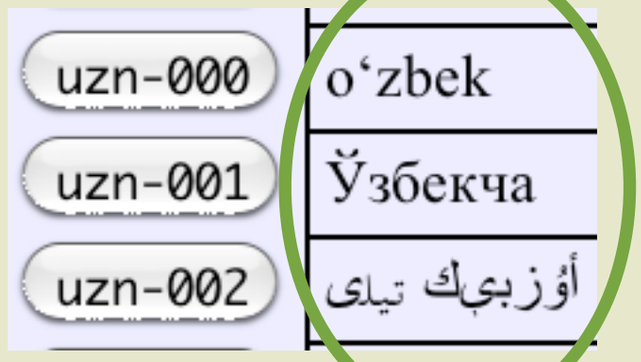


Open resource development

Language varieties:

- Literary standards
- Dialects
- Script-specific varieties
- Orthographic standards
- Controlled languages
- Standard codes for countries, chemical elements, etc.





ISO 639-2, 3, 5

Open resource development

Language-variety codes: example of Western Armenian

- PanLex: hye-001
- BCP 47: hy-arevmda
- Glottolog glottocodes: west2348
- MultiTree: hye-war
- WALS Codes: arw
- Linguasphere: 57-AAA-ac
- Lexvo: http://lexvo.org/id/iso639-3/hye
- Wikidata: Q180945
- Freebase:http://www.freebase.com/m/01tzg9
- ISO 639-1: hy
- ISO 639-2 (B): arm
- ISO 639-2 (T): hye
- ISO 639-3: hye

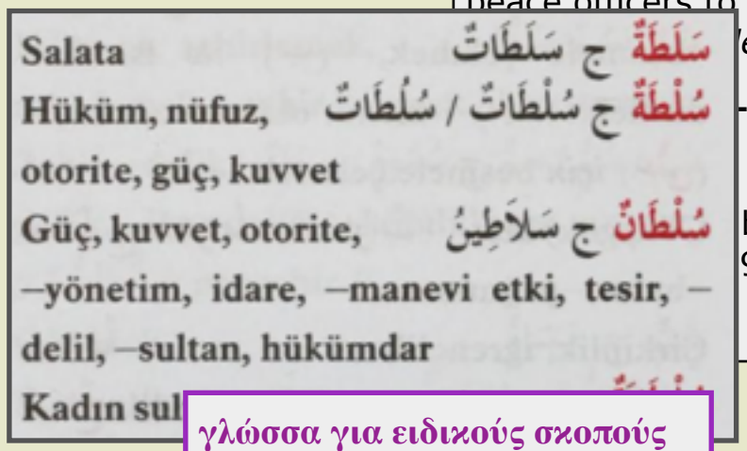
} Armenian generally

Open resource development

More sources, digital and printed

5500 acquired, 1700 consulted

- Monolingual dictionaries
- Bilingual dictionaries
- Multilingual dictionaries
- Wiktionaries
- Glossaries
- Vocabularies
- Wordlists
- Terminologies
- Wordnets
- Thesauri
- Standards
- Vocabulary databases
- Locale databases



Arrest: ᑎᒍᓱᐅᓂᖅ: Tigujauniq: Arrestation

The act of placing a person in custody, according to law. The powers of ordinary citizens and peace officers to arrest a person are set out in …e, 1996, Part XVI.

…ᖅ: Ikitittiniq: Crime

…berately setting fire to property. …996, sections 433-436.

γλώσσα για ειδικούς σκοπούς
MT (70.20)
Da: fagsprog
De: Fachsprache
En: language for special purposes
Es: lenguaje especializado
Fi: kieli tiettyihin tarkoituksiin
Fr: langage spécialisé
He: שפה למטרות מיוחדות
Hu: szaknyelv
It: lingua speciale
Nl: vaktaal
Sv: fackspråk
BT γλώσσες

SE (English: Sweden)	
An tSualainn	·ga·
isveç	·az·
İsveç	·tr·
Iswidhan	·so·
Rootsi	·et·
Ruotsi	·fi·
Ruotta	*·se·*
Schweden	·de·
Schweede	·gsw·

Open resource development

More data. Currently:

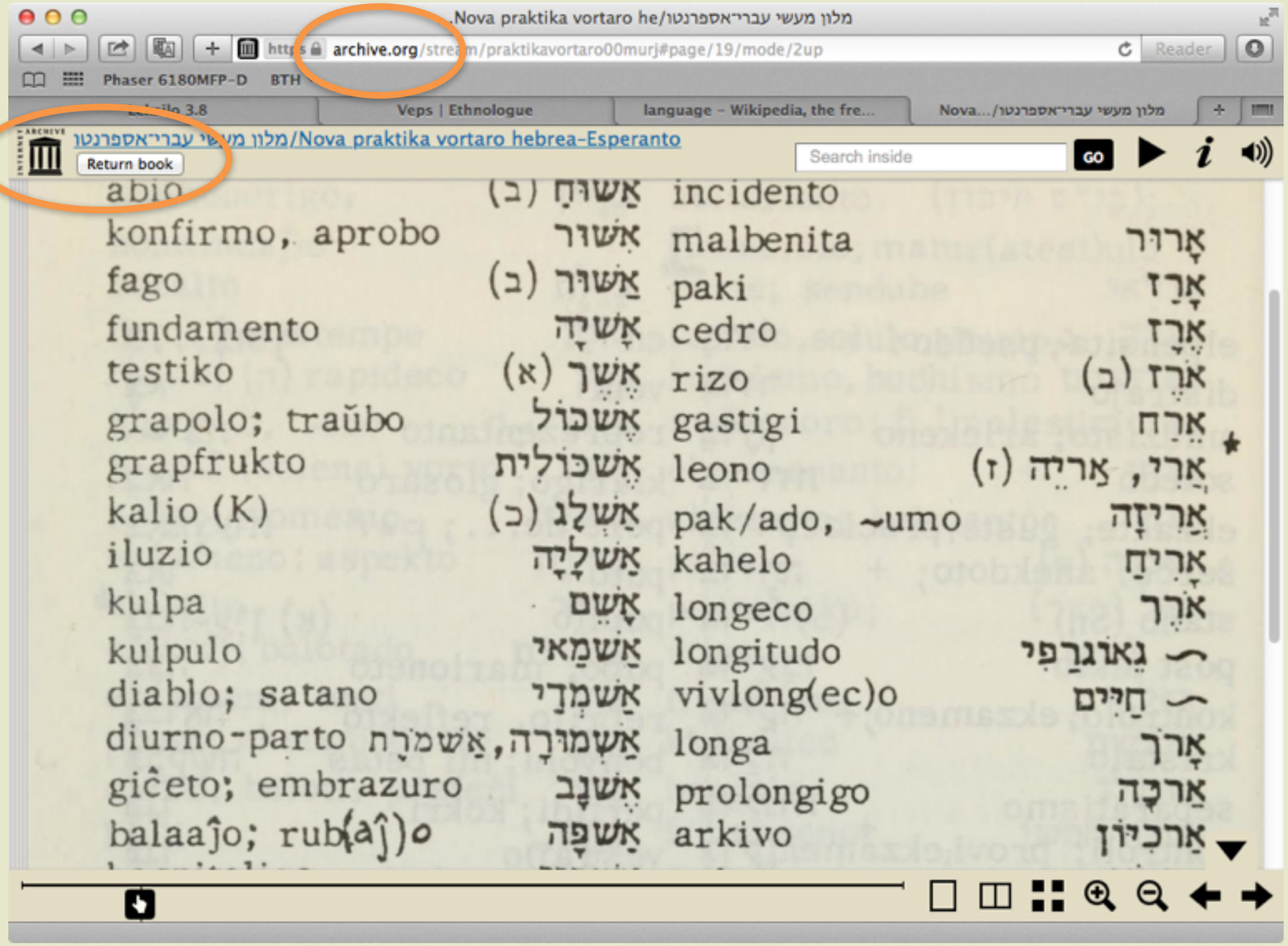
- 21 million *expressions* (≈ lemmas of lexemes)
- Expressions written in 60 scripts (Latin, 한글, Հայոց գրեր, தமிழ் அரிச்சுவடி, …)
- 10,000 language varieties
- 1.2 billion undirected pairwise translations

Open resource development

Access to raw data via:

- Internet Archive Open Library (printed originals)
- Links to original sources

Open resource development



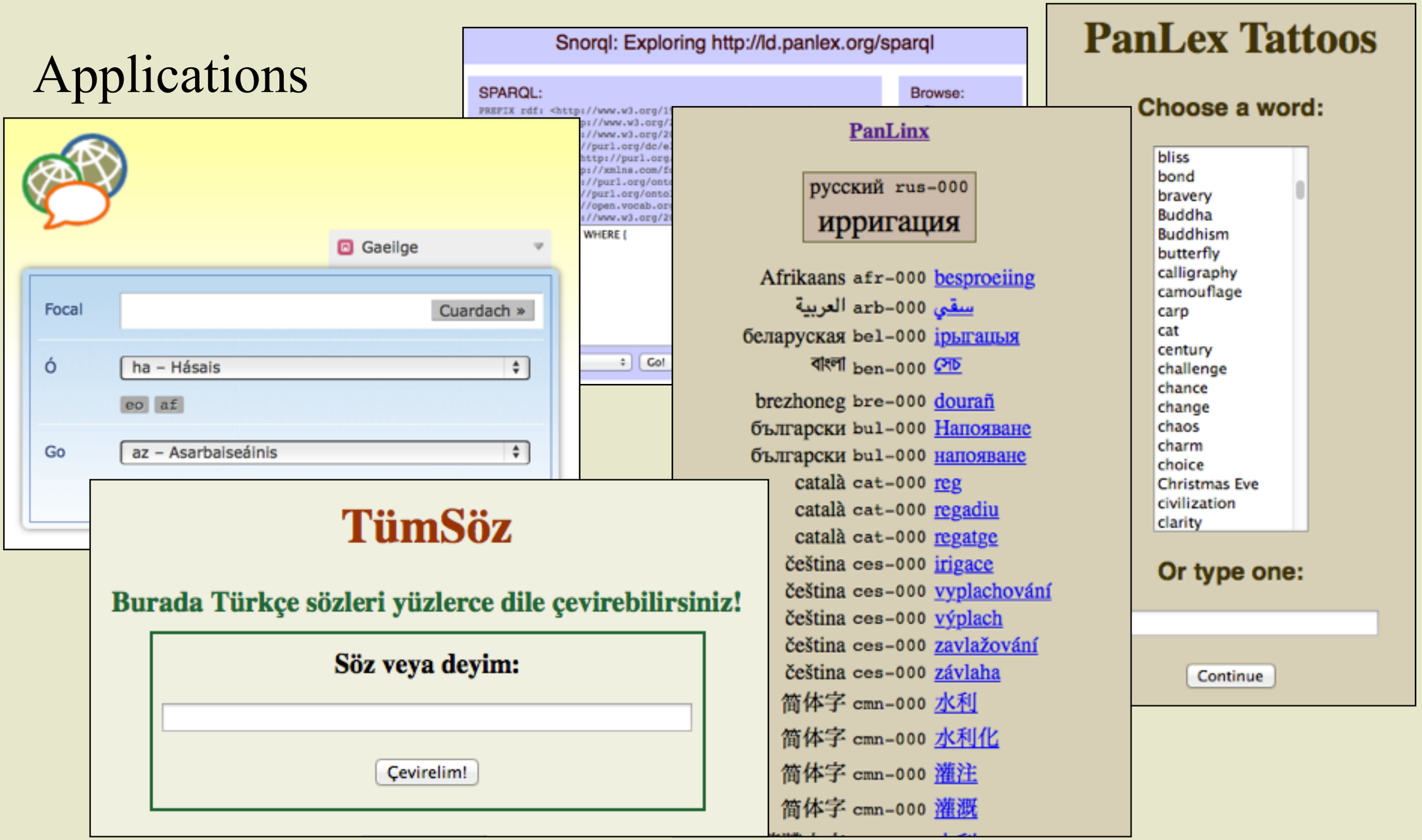
Open resource development

Access to processed data via:

- Monthly CSV, JSON, and XML dumps
- API (read-only)
- API apps for humans and search engines
- RDF interface linking (earlier) PanLex to DBpedia
- Expert web UI ("PanLem")
- Team only: CLI (psql)

Open resource development

Applications



Open resource development

API

- Provides live access to the database
- Public and free (within rate limits)
- Takes JSON queries and returns JSON responses for a variety of database objects
- Example query requesting translations of the English (eng-000) expression “church” into Western Armenian (hye-001), sorted by quality:

```
/ex { "uid": ["hye-001"], "trtt":
["church"], "truid": ["eng-000"],
"include": "trq", "sort": "trq desc" }
```

Open resource development

Source acquisition

- Prioritization of sources that are tractable (amenable to analysis) and which cover poorly documented languages
- Already ingested sources are mostly in born-digital formats (text, HTML, PDF, etc.)
- Increasing acquisition of print sources, purchased and scanned in partnership with the Internet Archive

Open resource development

Source workflow

- Identification: choice of a source from the source archive
- Consultation: determination of the logical structure of the source and what language varieties it contains
- Analysis: semi-automated computational extraction of usable data
- Submission: ingestion of the final source file into the PanLex database

Open resource development

Source consultation

Some of the Cebuano Words Recorded by Pigafetta in 1521

by Jessie Grace U. Rubrico

ENGLISH	OLD CEBUANO	MODERN CEBUANO	ENGLISH	OLD CEBUANO	MODERN CEBUANO
man	lac	lalaki	balances	tigban	timbangan
woman	paranpaon	babaye	weight	tahil	timbang
young woman	beni beni	dalaga	pearl	mutiara	mutya
married woman	babay	babayeng minyo	mother of pearl	tipay	tipay
buttocks	samput	balat-ang	pipe (musical instrument)	subing	plawta
thigh	paha	paa	disease of St. Job	alupalan	hubag
knee	tuhud	tuhod	bring me	palatin comorica	ambi
shin	bassag-bassag	bitiis	certain rice cakes	tinapai	puto/ bibingka
ankle	bolbol	buulbuul	good	main	maayo
heel	tiochid	kiting	no	tifale	dili
sole (foot)	lapa lapa	lapalapa	knife	capol/sundan	kutsilyo
gold	balaoan	bulawan	scissors	catle	gunting
silver	pilla	plata/pilak	to shave	chunthinch	mamalbas
brass	concach	tumbaga/ bronse	well adorned man	pixao	pustorawo

Open resource development

Source analysis

- Tabularization: transformation of source data into well-defined tables with one entry per row
- Serialization: normalization of tabularized data and conversion into a format that can be validated and ingested into the PanLex database
- Suite of tools written in Perl developed to streamline the process (http://github.com/longnow/panlex-tools)

Open resource development

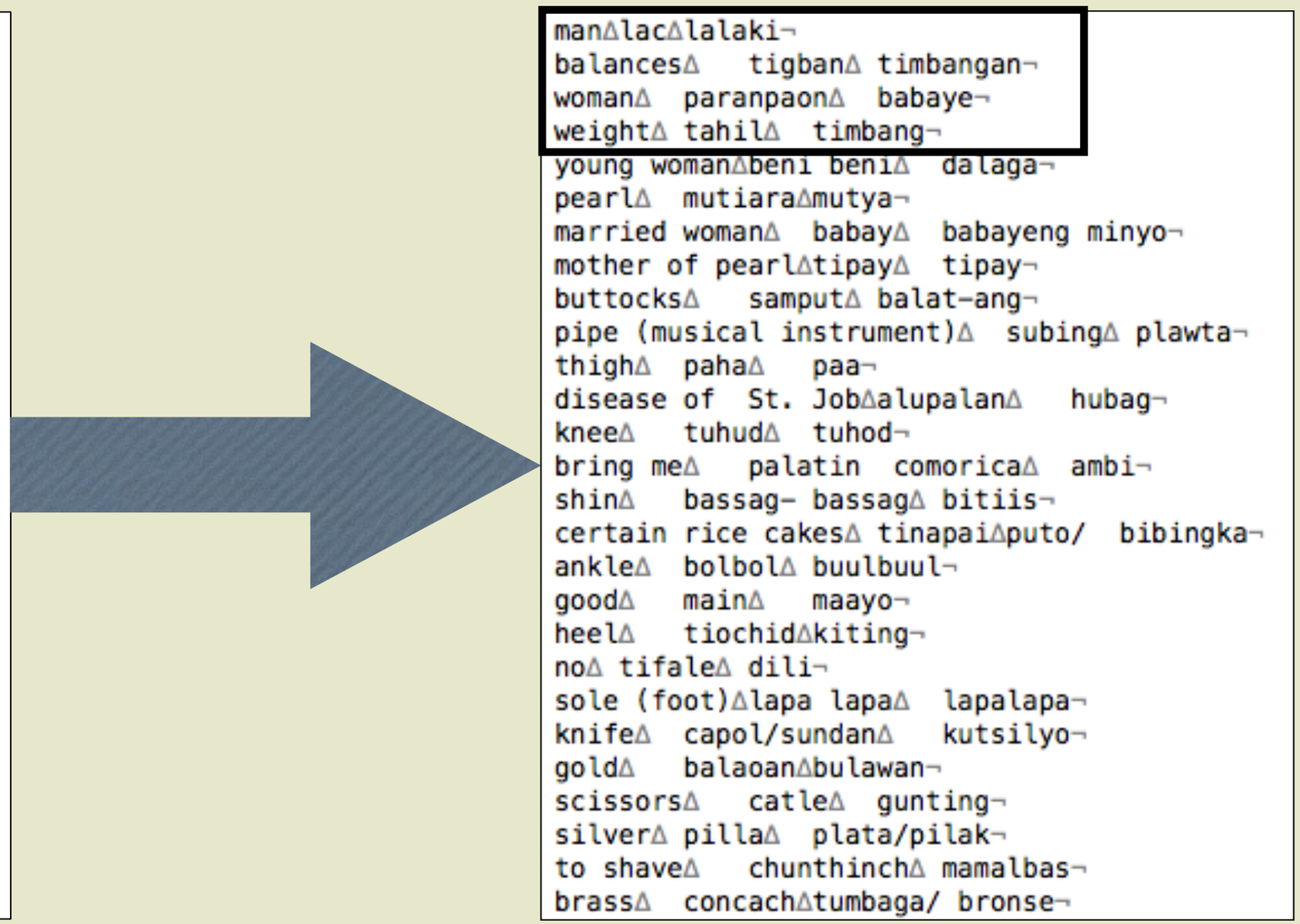
Tabularization: methods

- Custom scripts (usually Perl) using regular expressions, HTML/XML parsers, etc.
- PDF-to-text conversion (with or without layout analysis)
- PDF-to-XML dump (preserves style information)
- Manual transcription (for scanned print sources)

Open resource development

Tabularization: HTML example

```
<tr>
<td>man</td>

<td>lac</td>

<td>lalaki</td>

<td>balances</td>

<td>tigban</td>

<td>timbangan</td>
</tr>

<tr>
<td>woman</td>

<td>paranpaon</td>

<td>babaye</td>

<td>weight</td>

<td>tahil</td>

<td>timbang</td>
</tr>
```



```
man∆lac∆lalaki¬
balances∆  tigban∆ timbangan¬
woman∆  paranpaon∆  babaye¬
weight∆ tahil∆  timbang¬
young woman∆beni beni∆  dalaga¬
pearl∆  mutiara∆mutya¬
married woman∆  babay∆  babayeng minyo¬
mother of pearl∆tipay∆  tipay¬
buttocks∆  samput∆ balat-ang¬
pipe (musical instrument)∆  subing∆ plawta¬
thigh∆  paha∆  paa¬
disease of  St. Job∆alupalan∆  hubag¬
knee∆  tuhud∆  tuhod¬
bring me∆  palatin  comorica∆  ambi¬
shin∆  bassag- bassag∆ bitiis¬
certain rice cakes∆ tinapai∆puto/  bibingka¬
ankle∆  bolbol∆ buulbuul¬
good∆  main∆  maayo¬
heel∆  tiochid∆kiting¬
no∆ tifale∆ dili¬
sole (foot)∆lapa lapa∆  lapalapa¬
knife∆  capol/sundan∆  kutsilyo¬
gold∆  balaoan∆bulawan¬
scissors∆  catle∆  gunting¬
silver∆ pilla∆  plata/pilak¬
to shave∆  chunthinch∆ mamalbas¬
brass∆  concach∆tumbaga/ bronse¬
```

Open resource development

Tabularization: PDF example with text styles coding important information

revivir *vi* chedlane', chela' ši'i
revocar *vt* checa'a
revolcar 1. *vt* chchix̲ chtol̲e
2. *v prnl* chas chata', chbix̲ chtol̲e
revolver *vt* 1. chc̲hix̲e, chyitje
2. chta *(líquido)*
rey *m* rey
rezar *vi* chon rsar

Open resource development

Tabularization output of previous example

```
revolcarΔ    vtΔ chchix  chtol e¬
revolcarΔ    v prnlΔ chas chata'▸chbix_ chtol_e¬
revolverΔ    vtΔ chc_hix_e▸chyitje¬
revolver (líquido)Δ vtΔ chta¬
reyΔmΔ  rey¬
rezarΔ  viΔ chon rsar¬
```

Open resource development

Serialization: methods

- Tagging of columns as expressions, definitions, word classes, metadata, etc.
- Recategorization of non-lemmatic portions of expressions as definitions (e.g. parenthesized text) or word classes (e.g. question marks)
- Normalization of strings as expressions or definitions on the basis of length, Unicode characters, or attestation in PanLex

Open resource development

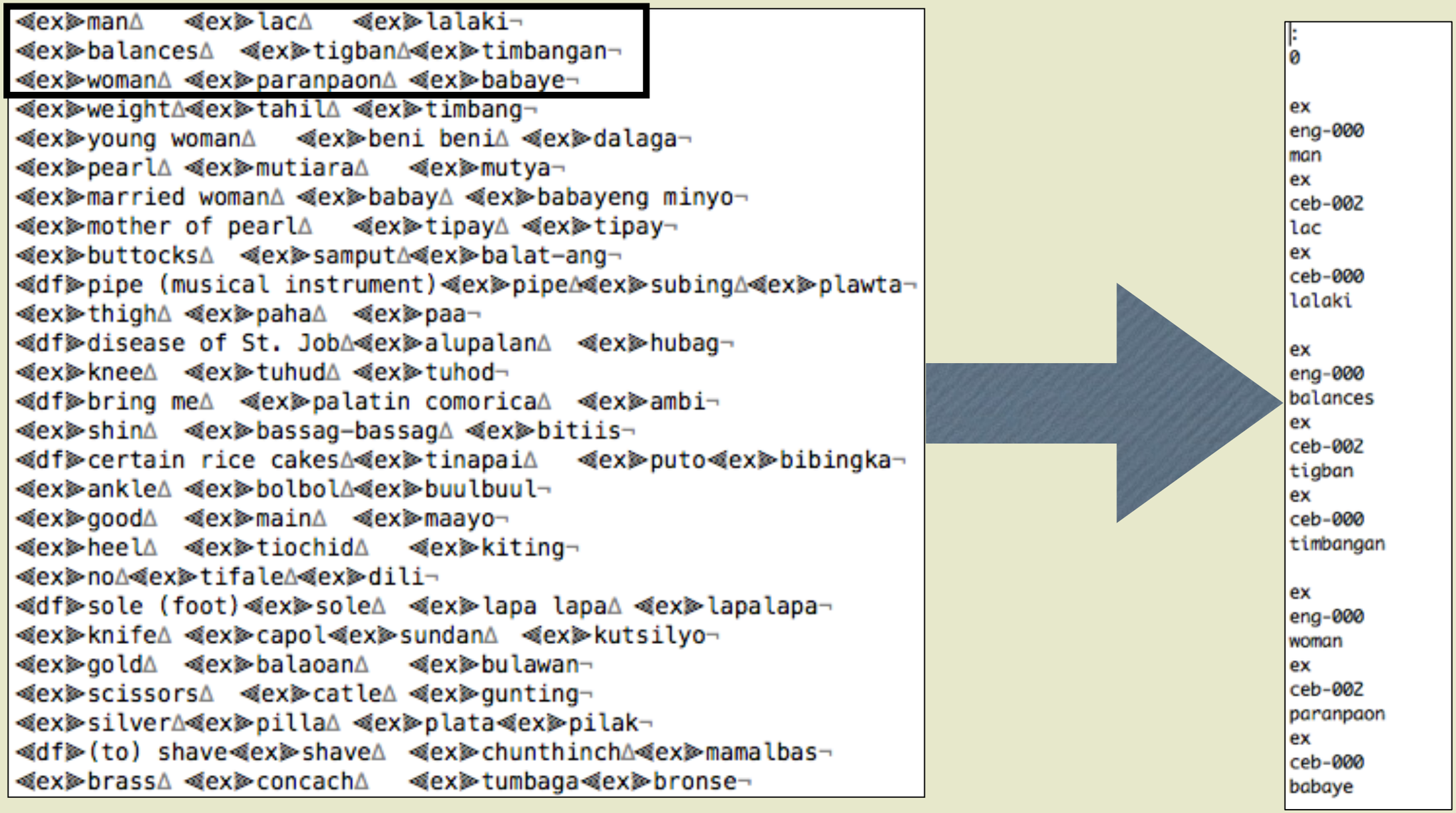
Serialization: tagging and normalization example

```
man∆lac∆lalaki¬
balances∆  tigban∆ timbangan¬
woman∆  paranpaon∆  babaye¬
weight∆ tahil∆  timbang¬
young woman∆beni beni∆  dalaga¬
pearl∆  mutiara∆mutya¬
married woman∆  babay∆  babayeng minyo¬
mother of pearl∆tipay∆  tipay¬
buttocks∆  samput∆ balat-ang¬
pipe (musical instrument)∆  subing∆ plawta¬
thigh∆  paha∆  paa¬
disease of  St. Job∆alupalan∆  hubag¬
knee∆  tuhud∆  tuhod¬
bring me∆  palatin  comorica∆  ambi¬
shin∆  bassag- bassag∆ bitiis¬
certain rice cakes∆ tinapai∆puto/  bibingka¬
ankle∆  bolbol∆ buulbuul¬
good∆  main∆  maayo¬
heel∆  tiochid∆kiting¬
no∆ tifale∆ dili¬
sole (foot)∆lapa lapa∆  lapalapa¬
knife∆  capol/sundan∆  kutsilyo¬
gold∆  balaoan∆bulawan¬
scissors∆  catle∆  gunting¬
silver∆ pilla∆  plata/pilak¬
to shave∆  chunthinch∆ mamalbas¬
brass∆  concach∆tumbaga/ bronse¬
```

```
◀ex▶man∆  ◀ex▶lac∆  ◀ex▶lalaki¬
◀ex▶balances∆  ◀ex▶tigban∆◀ex▶timbangan¬
◀ex▶woman∆ ◀ex▶paranpaon∆ ◀ex▶babaye¬
◀ex▶weight∆◀ex▶tahil∆ ◀ex▶timbang¬
◀ex▶young woman∆  ◀ex▶beni beni∆ ◀ex▶dalaga¬
◀ex▶pearl∆ ◀ex▶mutiara∆  ◀ex▶mutya¬
◀ex▶married woman∆ ◀ex▶babay∆ ◀ex▶babayeng minyo¬
◀ex▶mother of pearl∆  ◀ex▶tipay∆ ◀ex▶tipay¬
◀ex▶buttocks∆  ◀ex▶samput∆◀ex▶balat-ang¬
◀df▶pipe (musical instrument)◀ex▶pipe∆◀ex▶subing∆◀ex▶plawta¬
◀ex▶thigh∆ ◀ex▶paha∆  ◀ex▶paa¬
◀df▶disease of St. Job∆◀ex▶alupalan∆  ◀ex▶hubag¬
◀ex▶knee∆  ◀ex▶tuhud∆ ◀ex▶tuhod¬
◀df▶bring me∆  ◀ex▶palatin comorica∆  ◀ex▶ambi¬
◀ex▶shin∆  ◀ex▶bassag-bassag∆ ◀ex▶bitiis¬
◀df▶certain rice cakes∆◀ex▶tinapai∆  ◀ex▶puto◀ex▶bibingka¬
◀ex▶ankle∆ ◀ex▶bolbol∆◀ex▶buulbuul¬
◀ex▶good∆  ◀ex▶main∆  ◀ex▶maayo¬
◀ex▶heel∆  ◀ex▶tiochid∆  ◀ex▶kiting¬
◀ex▶no∆◀ex▶tifale∆◀ex▶dili¬
◀df▶sole (foot)◀ex▶sole∆  ◀ex▶lapa lapa∆ ◀ex▶lapalapa¬
◀ex▶knife∆ ◀ex▶capol◀ex▶sundan∆  ◀ex▶kutsilyo¬
◀ex▶gold∆  ◀ex▶balaoan∆  ◀ex▶bulawan¬
◀ex▶scissors∆  ◀ex▶catle∆ ◀ex▶gunting¬
◀ex▶silver∆◀ex▶pilla∆ ◀ex▶plata◀ex▶pilak¬
◀df▶(to) shave◀ex▶shave∆  ◀ex▶chunthinch∆◀ex▶mamalbas¬
◀ex▶brass∆ ◀ex▶concach∆  ◀ex▶tumbaga◀ex▶bronse¬
```

Open resource development

Serialization: generation of final source file



People

Project team:

- David Kamholz, Lexical Data Specialist
- Jonathan Pool, Project Director
- Susan Colowick, Research Associate
- Laura Welcher + Emily Bender + Steven Bird, Steering Committee

Original team, University of Washington Turing Center:

Oren Etzioni	*Stephen Soderland*	*Mausam*
Marcus Sammer	*Kobi Reiter*	*Michael Skinner*
Christopher Lim	*Janara Christensen*	*Michael Schmitz*

Partners

- University of Washington Turing Center (initiator): http://turing.cs.washington.edu
- The Long Now Foundation (sponsor): http://longnow.org
- The Rosetta Project: http://rosettaproject.org
- Internet Archive: http://archive.org
- Unicode Consortium: http://unicode.org
- Global Glossary: http://globalglossary.org
- Open Knowledge Foundation: http://okfn.org

Publications

Papers:

Timothy Baldwin, Jonathan Pool, Susan M. Colowick, "PanLex and LEXTRACT: Translating all Words of all Languages of the World", Coling 2010.

Jonathan Pool, "Panlingual Globalization", *Handbook of Language and Globalization* 2010.

Francesca Gola, "An analysis of translation divergence patterns using PanLex translation pairs", MS thesis, Univ of Wash, 2012.

Patrick Westphal, Claus Stadler, Jonathan Pool, "Countering language attrition with PanLex and the Web of Data", *Semantic Web Journal* 2014.

David Kamholz, Jonathan Pool, Susan M. Colowick, "PanLex: Building a Resource for Panlingual Lexical Translation", LREC 2014.

Presentations:

DELPH-IN Summit 2011

IUC (Internationalization and Unicode Conference) 2012.