KYOTO (ICT-211423) Intelligent Content and Semantics
Knowledge **Y**ielding **O**ntologies for **T**ransition-Based **O**rganization
http://www.kyoto-project.eu/

Event and Fact Mining

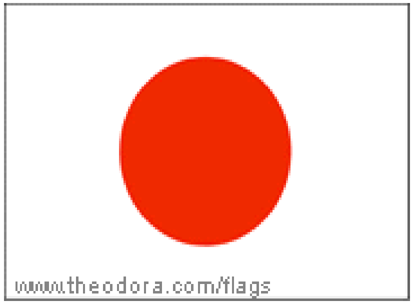
German Rigau
IXA group, UPV/EHU

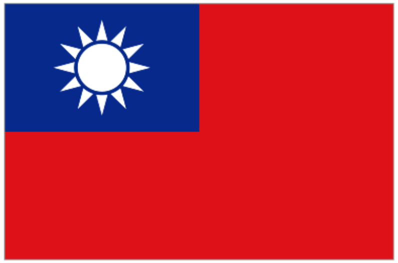
Final Review
April 8th, 2011, Berlin, Germany

KYOTO

European-Asian project

http://www.kyoto-project.eu/





COOPERATION

Final Review, April 8th, 2011, Berlin

ICT-211423

KYOTO (ICT-211423)

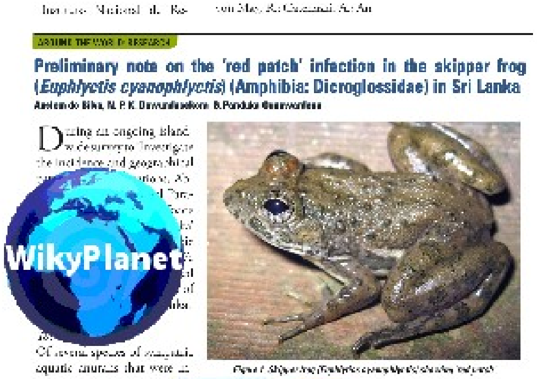
- Generic concept-based fact mining system
- Try to represent all factual information in text:
  - Fact = event+participants+role+time+place
- Using generic semantic models:
  - wordnets+shared ontology;
- With the possibility to extend it with a domain model;
- In a uniform and interoperable way for 7 different languages: English, Dutch, Spanish, Basque, Italian, Japanese and Chinese
- Tested on 10,000 documents

Knowledge Mining in Kyoto

- Concept mining (Tybot)
  - Extract terms and relations in a language
  - Map the terms to an existing wordnet
  - Ontologize terms to concepts and axioms
- Fact mining (**Kybot**)
  - Define **morpho-syntactic** and **semantic patterns** in text
  - Extract events from text
  - Collect events and extract facts

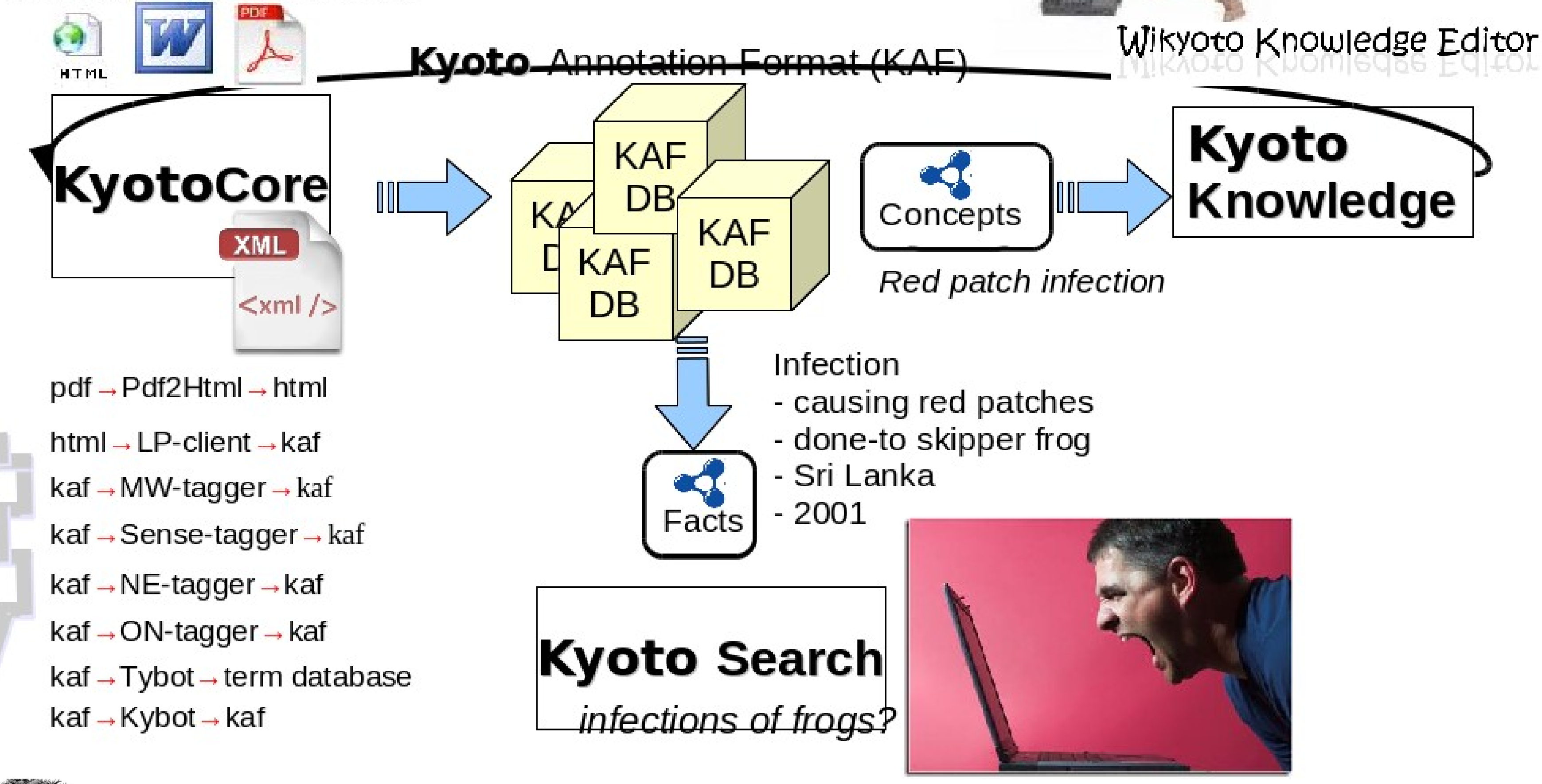
- For all languages!
- **KAF** (Kyoto Annotation Format) is the input of both:
  - Tybot: term extraction
  - Kybot: fact extraction

Kyoto System



Preliminary note on the 'red patch' infection in the skipper frog (*Euphlyctis cyanophlyctis*) (Amphibia: Dicroglossidae) in Sri Lanka

During an ongoing island wide survey to investigate the incidence and geographical [illegible]



Infection
- causing red patches
- done-to skipper frog
- Sri Lanka
- 2001

pdf → Pdf2Html → html

html → LP-client → kaf

kaf → MW-tagger → kaf

kaf → Sense-tagger → kaf

kaf → NE-tagger → kaf

kaf → ON-tagger → kaf

kaf → Tybot → term database

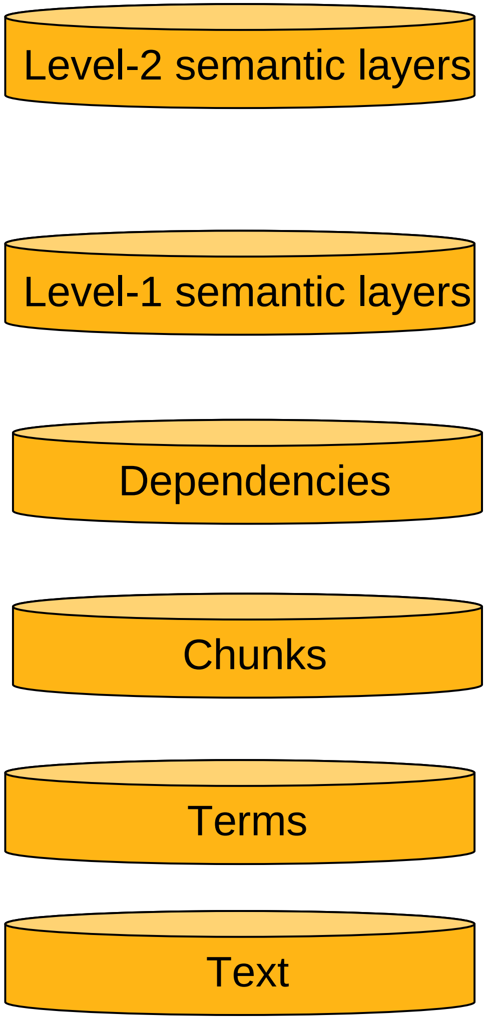
kaf → Kybot → kaf

Outline

- KAF
- Kyoto CORE for fact extraction
- Knowledge Architecture
- Mining module
- Kybot evaluation & benchmarking
- Future development

Kyoto Annotation Format (KAF)

- Based on Layered Annotation Format (ISO proposal, Ide and Romary 2002)
- Stand off annotation
- Uniform representation for 7 languages
- Sharing of semantic modules across different languages: multiword tagging, WSD, Named Entity recognition, Onto tagging and event/fact extraction
- Cross-lingual semantic search for 7 languages



Layers of Text and Terms

```
<kaf>
  <text>
   <wf wid=”w1” page=”1” sent=”1” para=”1” fileoffset=”0,4”>large</wf>
   <wf wid=”w2” page=”1” sent=”1” para=”1” fileoffset=”6,14”>migratory</wf>
   <wf wid=”w3” page=”1” sent=”1” para=”1” fileoffset=”16,20”>birds</wf>
     </text>
     <terms>
       <term tid=”t1” type=”open” lemma=”large” pos=”G”>
         <span id=”w1”/><!-- refers to ”large” (w1) -->
       </term>
       <term tid=”t2” type=”open” lemma=”migratory bird” pos=”N”>
         <span id=”w2”/><span id=”w3”/>
        <!--refers to ”migratory”(w2)+”birds”(w3)-->
       </term>
     </terms>
    </kaf>
```

Layers of Chunks and Dependencies

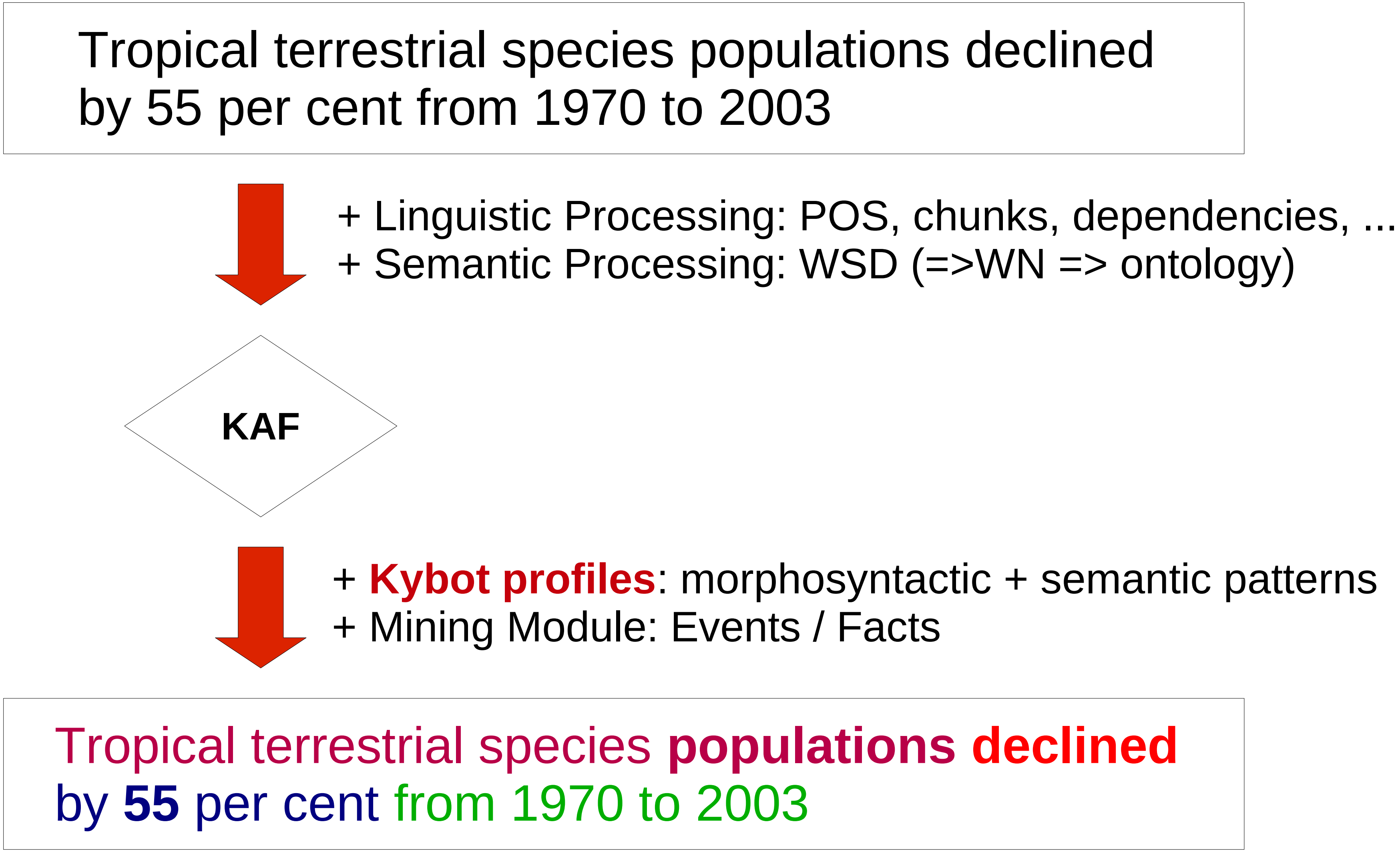
```
<kaf>
  <text>...</text><!-- defines w1, w2, w3 -->
  <terms>...</terms><!-- defines t1, t2 →

   <chunks>
      <chunk cid=”c1” head=”t2” phrase=”NP”>
        <span id=”t1”/><!-- refers to term: ”large” -->
        <span id=”t2”/><!-- refers to term: ”migratory bird” -->
      </chunk>
    </chunks>
    <deps>
      <!-- dependency: ”large” (t1) → ”migratory birds” (t2) -->
      <dep from=”t1” to=”t2” rfunc=”mod”/>
    </deps>

</kaf>
```

Semantic layers

```
<term tid="t4" type="open" lemma="population" pos="N">
    <span><target id="w4"/></span>
   <externalReferences>
   < externalRef resource="WN-3.0" ref="EN-30-00859568-n" conf="0.80 "/>
   < externalRef resource="WN-3.0" ref="EN-30-00257849-n" conf="0.13 />
   < externalRef resource="WN-3.0" ref="EN-30-00962397-n" conf="0.07 />
   <externalRef resource=“DOLCE-1.0" ref=“dolce#group" conf="0.80"/>
</externalReferences>
</term>
```

Important: all different meanings are represented but with different WSD scores! No interpretation is excluded.

Fact Mining: Kybots



Tropical terrestrial species populations declined by 55 per cent from 1970 to 2003

+ Linguistic Processing: POS, chunks, dependencies, ...
+ Semantic Processing: WSD (=>WN => ontology)

+ **Kybot profiles**: morphosyntactic + semantic patterns
+ Mining Module: Events / Facts

Tropical terrestrial species **populations declined** by **55** per cent from 1970 to 2003

KAF

- Based on current ISO proposals
- Language-neutral annotation of text,
  - concepts, facts,…
  - Multilingual
- Interoperable across linguistic processors
  - KAF is the basis for integration
- Flexible and extendible

Linguistic Processors

- KAF (Kyoto Annotation Format)
  - English: **Synthema**
  - Dutch: **VUA**
  - Italian: **Synthema**
  - Basque: **EHU**
  - Spanish: **EHU**
  - Chinese: **AS**
  - Japanese: **NICT**

- Pdf2html: **Irion**
- MW detection: **VUA**
- Word Sense Disambiguation module (UKB): **EHU**
- NE Tagger: **Irion**
- OntoTagger: **CNR-ILC, EHU**

- PipeT: **VUA**

Linguistic Processors

- KAF XML files include sections for:
  - Word forms
  - Terms / Items
  - Chunks: grouping of sequences of terms
  - Dependencies: syntactic relations between terms
  - WSD: WN senses of the term
  - Ontological references of the term:
    - Base Concepts
    - Explicit ontology
  - Events
  - Locations, Time expressions
  - ...

Fact Mining: Kybot profiles

- Kybot profiles consist of:
  - Morpho-syntactic conditions
    - LPs outcomes
  - Semantic conditions:
    - WordNets + Ontologies
    - **Inferencing** on WN & ontology !
  - Output Template
    - Event / Fact descriptions

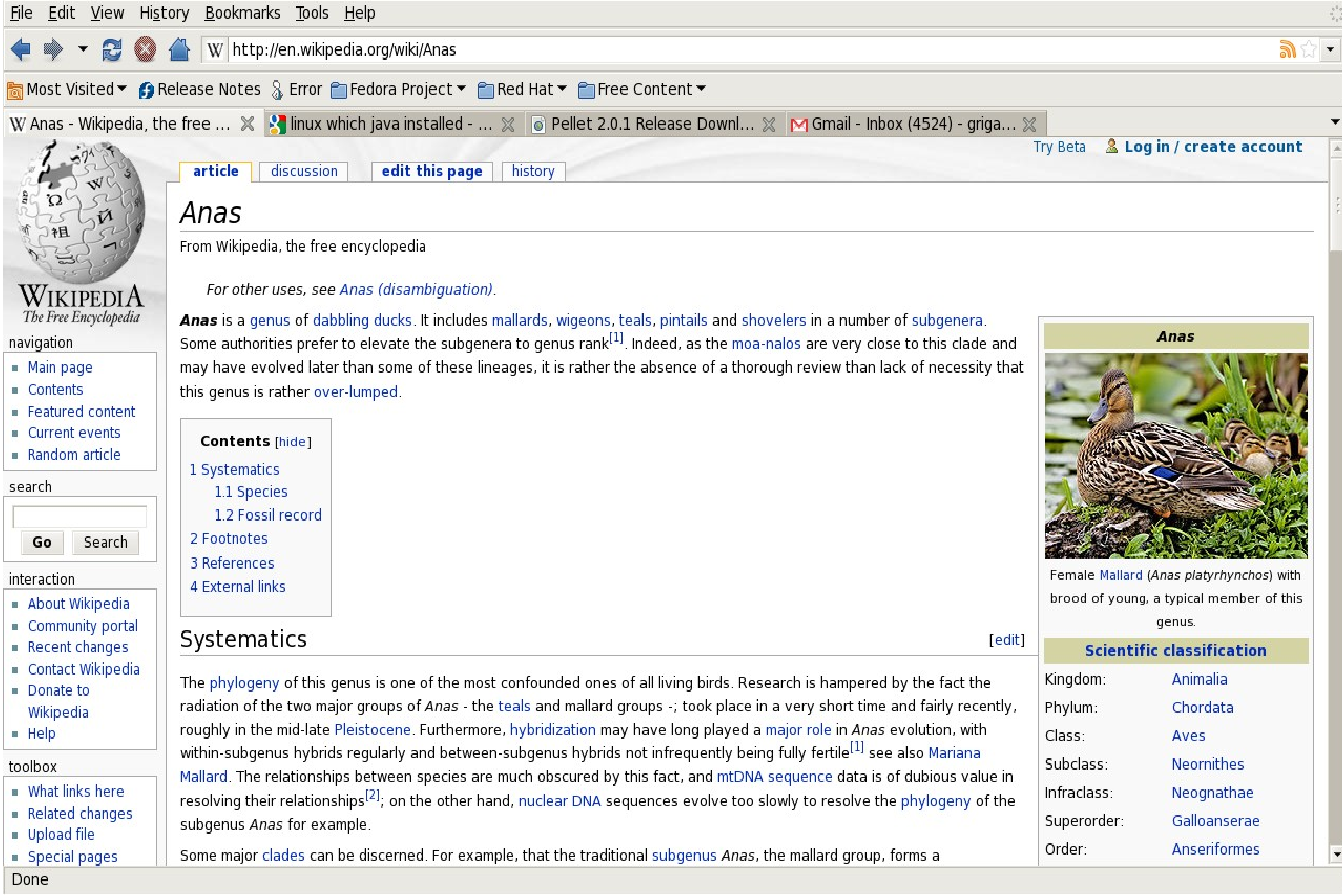
Fact Mining: Kybot profiles

- For each sentence :
  - **IF** Morpho-sintactic Conditions match **and**
    - Semantic Conditions hold
  - **THEN**
    - generate the Output Template

- How to make **efficient** inferencing on WN & ontology?
  - ... while processing very large volumes of KAF
  - WN => Nominal and Verbal Base Concepts !
  - Ontology => Explicit Ontology !
  - **Off-line inferencing** !

Knowledge Architecture

- Modeling **domain** knowledge ...
  - for **seven languages**
  - each one encoding diverse **phenomena**
    - ... *migratory bird* ... *birds that migrate* ...
    - ... *migratory path / pattern* ...
    - ... *migration of ducks* ...
  - general and specialized **terminology**
    - ... *footprint ... greenhouse gas ...*
    - ... *Humber estuary ...*
    - ... *SAC features – littoral and sub-tidal ...*
    - ... *SPA ...*
    - ... *cape teal ... anas capensis ...*
    - ... *Yellow-billed Pintail ...*
    - ...



Anas

From Wikipedia, the free encyclopedia

For other uses, see Anas (disambiguation).

Anas is a genus of dabbling ducks. It includes mallards, wigeons, teals, pintails and shovelers in a number of subgenera. Some authorities prefer to elevate the subgenera to genus rank[1]. Indeed, as the moa-nalos are very close to this clade and may have evolved later than some of these lineages, it is rather the absence of a thorough review than lack of necessity that this genus is rather over-lumped.

Anas

Female Mallard (*Anas platyrhynchos*) with brood of young, a typical member of this genus.

Scientific classification

Kingdom:	Animalia
Phylum:	Chordata
Class:	Aves
Subclass:	Neornithes
Infraclass:	Neognathae
Superorder:	Galloanserae
Order:	Anseriformes

Contents [hide]

1 Systematics
1.1 Species
1.2 Fossil record
2 Footnotes
3 References
4 External links

Systematics

[edit]

The phylogeny of this genus is one of the most confounded ones of all living birds. Research is hampered by the fact the radiation of the two major groups of *Anas* - the teals and mallard groups -; took place in a very short time and fairly recently, roughly in the mid-late Pleistocene. Furthermore, hybridization may have long played a major role in *Anas* evolution, with within-subgenus hybrids regularly and between-subgenus hybrids not infrequently being fully fertile[1] see also Mariana Mallard. The relationships between species are much obscured by this fact, and mtDNA sequence data is of dubious value in resolving their relationships[2]; on the other hand, nuclear DNA sequences evolve too slowly to resolve the phylogeny of the subgenus *Anas* for example.

Some major clades can be discerned. For example, that the traditional subgenus *Anas*, the mallard group, forms a

Knowledge Repositories for the domain

- **Term database**: 100,000 terms per language
- **DBPedia**: 2.6 million things
- **GeoNames**: 8 million geographical names
- **Species 2000**: 2.1 million species
- **Wordnets** for 7 languages:
  - about 50,000 to 120,000 synsets per language
  - Domain WN: ~2,000 concepts
- **Ontologies**: SUMO, DOLCE-Lite, SIMPLE
  - Kyoto ontology 3.1: 1500 classes
- ...

Knowledge Integration in KYOTO

- Should all knowledge be stored in the **central ontology**?
  - The knowledge is (still) **too large**
  - The knowledge to be stored is **too diverse**
  - Diferent types of knowledge require **different inferencing capabilities**

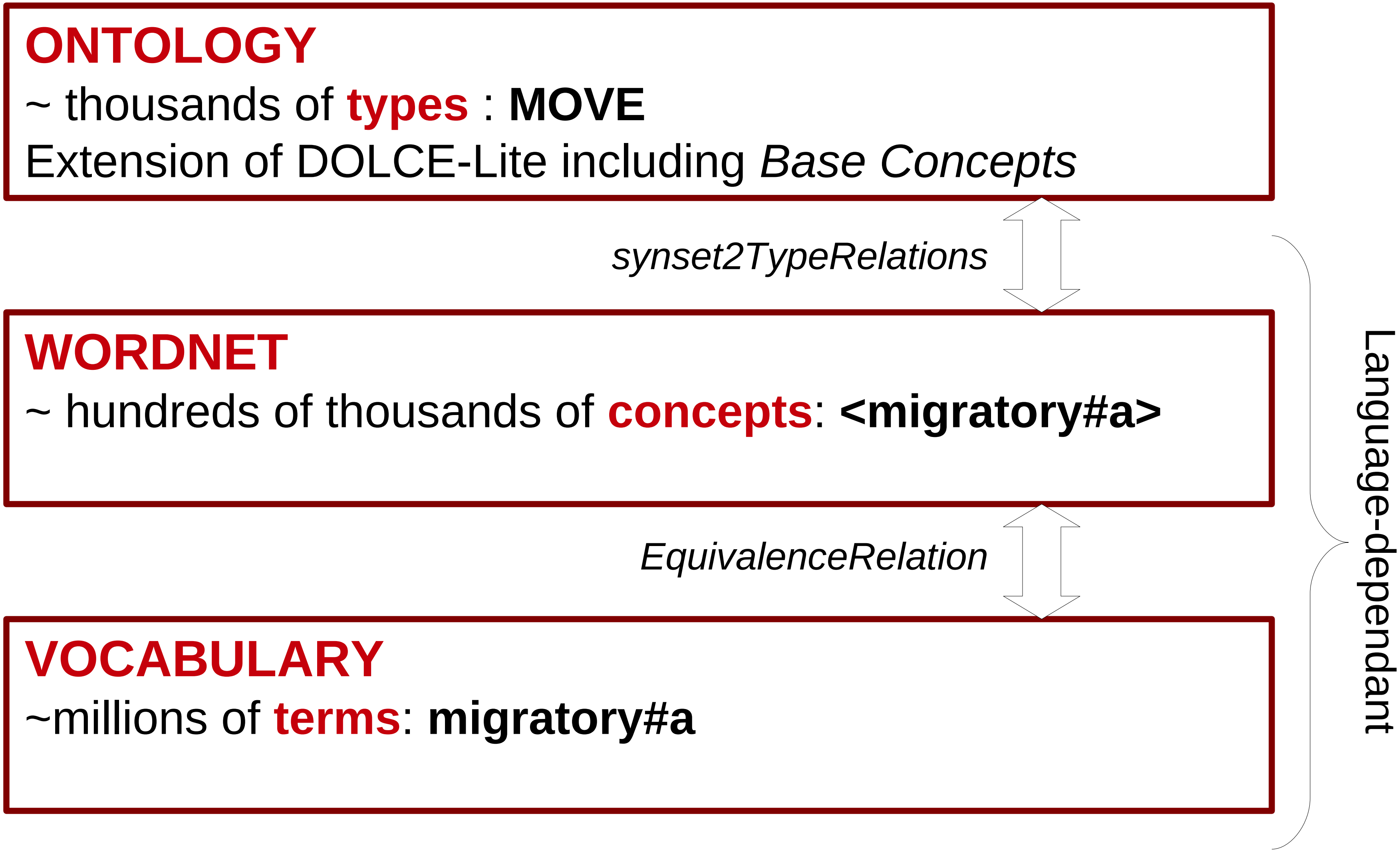
Knowledge Integration in KYOTO

- A model of **division of labour** (along the lines of Putnam 1975) in which knowledge is stored in **3 layers**:
  - Vocabularies, term databases, etc. (SKOS)
  - WordNet (WN-LMF)
  - Ontology (OWL-DL)

- **Mapping relations** that support the division of labour
  - language-specific conceptualizations

- Each layer supports different types of **inferencing**
  - SparQL queries
  - Graph algorithms (UKB, SSID+)
  - Formal reasoning (OWL-DL reasoners, FACT++)

KYOTO Knowledge Model



ONTOLOGY

~ thousands of **types** : **MOVE**

Extension of DOLCE-Lite including *Base Concepts*

synset2TypeRelations

WORDNET

~ hundreds of thousands of **concepts**: **<migratory#a>**

EquivalenceRelation

VOCABULARY

~millions of **terms**: **migratory#a**

Language-dependant

Automatic selection of Base Concepts

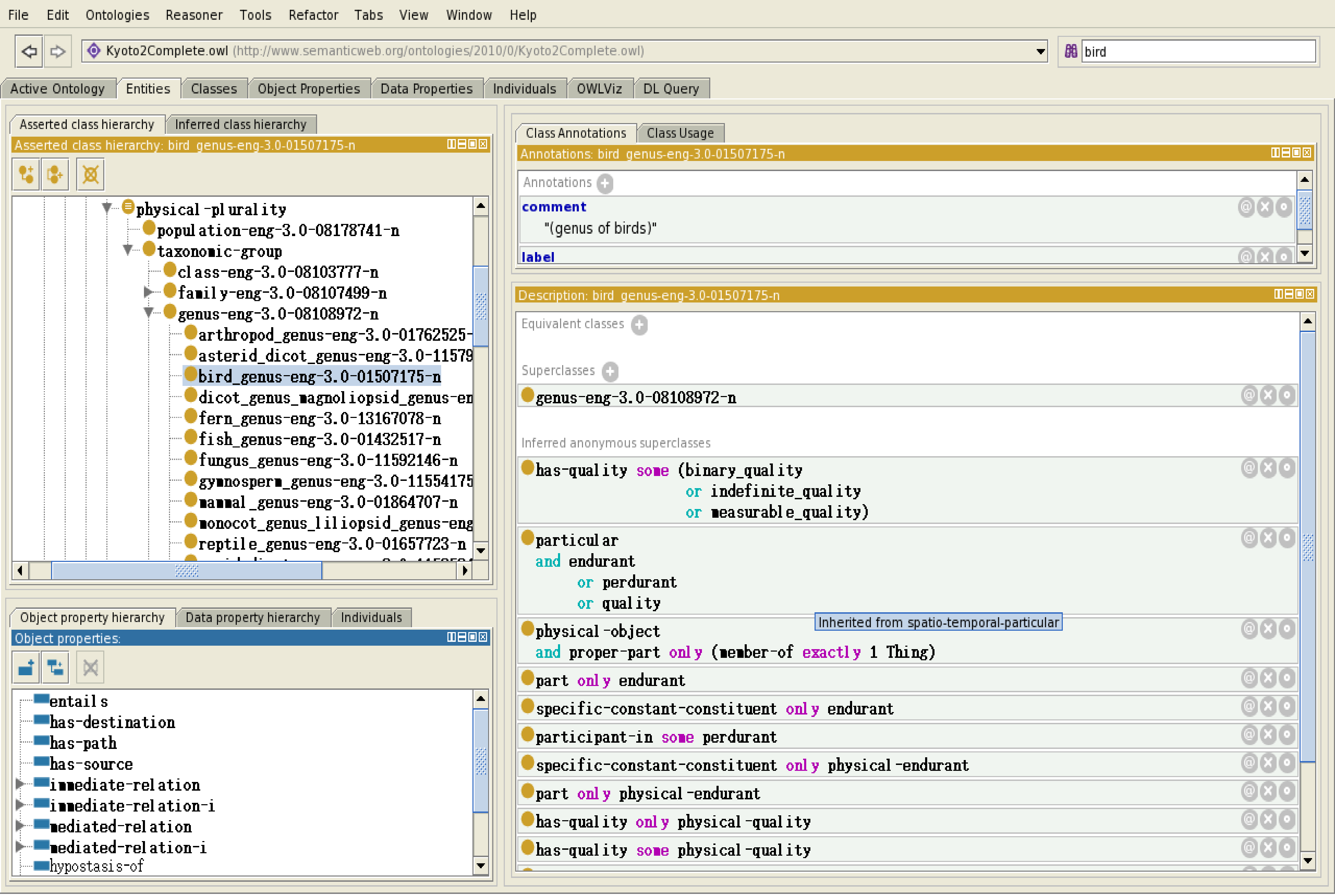
- **Base Concepts** are the result of a compromise between two **conflicting** principles of characterization:
  - Represent as many concepts as possible
  - Represent as many features as possible
- Base Concepts typically occur in the middle of semantic hierarchies

Automatic selection of Base Concepts

freq.	#rel	synset
2338	18	00017954-n group 1,grouping 1
0	19	05962976-n social group 1
729	**37**	05997592-n organisation 2,organization 1
30	10	06002286-n establishment 2,institution 1
15	**12**	**06023733-n faith 3,religion 2**
62	5	06024357-n Christianity 2,**church 1**,Christian church 1
11	14	00001740-n entity 1,something 1
51	29	00009457-n object 1,physical ob ject 1
1	39	00011937-n artifact 1,artefact 1
68	63	03431817-n construction 3,structure 1
50	**79**	**02347413-n building 1,edifice 1**
0	11	03135441-n place of worship 1,house of prayer 1
59	**19**	02438778-n **church 2**,church building 1
25	20	00017487-n act 2,human action 1,human activity 1
611	**69**	00261466-n activity 1
2	5	00662816-n ceremony 3
0	**11**	**00663517-n religious ceremony 1,religious ritual 1**
243	7	00666638-n service 3,religious service 1,divine service 1
11	1	00666912-n **church 3**,church service 1

WordNet to Ontology mappings

- By using the Base Concepts as an abstraction layer, all WN synsets have been connected to the Ontology
  - 297 **nominal** Base Concepts
  - 578 **verbal** Base Concepts
- WN hierarchy for nouns and verbs
- Non hierarchical relations for **adjectives**
  - **Morpho-semantic links** from WN



Kyoto2Complete.owl (http://www.semanticweb.org/ontologies/2010/0/Kyoto2Complete.owl)

bird

Asserted class hierarchy: bird_genus-eng-3.0-01507175-n

```
physical-plurality
    population-eng-3.0-08178741-n
    taxonomic-group
        class-eng-3.0-08103777-n
        family-eng-3.0-08107499-n
        genus-eng-3.0-08108972-n
            arthropod_genus-eng-3.0-01762525-
            asterid_dicot_genus-eng-3.0-11579
            bird_genus-eng-3.0-01507175-n
            dicot_genus_magnoliopsid_genus-en
            fern_genus-eng-3.0-13167078-n
            fish_genus-eng-3.0-01432517-n
            fungus_genus-eng-3.0-11592146-n
            gymnosperm_genus-eng-3.0-11554175
            mammal_genus-eng-3.0-01864707-n
            monocot_genus_liliopsid_genus-eng
            reptile_genus-eng-3.0-01657723-n
```

Annotations: bird_genus-eng-3.0-01507175-n

comment
"(genus of birds)"

label

Description: bird_genus-eng-3.0-01507175-n

Superclasses

genus-eng-3.0-08108972-n

Inferred anonymous superclasses

```
has-quality some (binary_quality
                  or indefinite_quality
                  or measurable_quality)

particular
 and endurant
      or perdurant
      or quality

physical-object
 and proper-part only (member-of exactly 1 Thing)

part only endurant

specific-constant-constituent only endurant

participant-in some perdurant

specific-constant-constituent only physical-endurant

part only physical-endurant

has-quality only physical-quality

has-quality some physical-quality
```

Inherited from spatio-temporal-particular

Object properties:

```
entails
has-destination
has-path
has-source
immediate-relation
immediate-relation-i
mediated-relation
mediated-relation-i
hypostasis-of
```

Wordnet ontology relations

Rigid vs. **Non-rigid**

Rigid

- Synset:Endurant; Synset:Perdurant; Synset:Quality:
- sc_equivalenceOf

Non-rigid:

- Synset:Role; Synset:Endurant
- sc_domainOf: range of ontology types that restricts a role
- sc_playRole: role that is being played

Rigidity can be detected automatically (**Rudify**, 80% precision, IAG 80%) and is stored in wordnets as attributes to synsets

KYOTO Ontology

Generic ontology:

- 1964 **c**lasses, 350 **o**bject properties, 3053 **a**xioms:
  - Top (260 c;322 p;575 a)
  - Middle (279 c;15 p;387 a)
  - Domain layer (1425 c;13 p;2091 a)
- New classes to represent **all** nouns, verbs and adjectives in WN, using Base Concepts
- Model process, qualities in terms of opposition relations, and changes in quality regions
- **Explicit** ontology contains 30,000 statements

Wordnet ontology-relations

sc_**equivalenceOf**

sc_**subclassOf**

sc_**domainOf**

sc_**playRole**

sc_**participantOf**

sc_**hasState**

- *migratory bird*
- → sc_**domainOf** *ont:bird*
- → sc_**playRole** *ont:done-by*
- → sc_**participantOf** *ont:migration*

Lexicalization of process-related concepts

{obstruct, obturate, impede, occlude, jam, block, close up}Verb, English
-> sc_equivalenceOf ***ObstructionPerdurant***
{obstruction, obstructor, obstructer, impediment, impedimenta}Noun, English
-> sc_domainOf ***PhysicalObject***
-> sc_playRole ***ObstructingRole***
{migration birds}Noun, English
-> sc_domainOf ***Bird***
-> sc_playRole ***MigratorRole***
{migration}Verb, English
-> sc_ equivalenceOf ***MigrationProcess***
{migration area}Noun, English
-> sc_domainOf ***PhysicalObject***
-> sc_ playRole ***TargetRole***

Lexicalization of process-related concepts

{create, produce, make}Verb, English
-> sc_ equivalenceOf ***ConstructionProcess***

{artifact, artefact}Noun, English
-> sc_domainOf ***PhysicalObject***
-> sc_playRole ***ConstructedRole***

{kunststof}Noun, Dutch // lit. *artifact substance*
-> sc_domainOf ***AmountOfMatter***
-> sc_playRole ***ConstructedRole***

{meat}Noun, English
-> sc_domainOf ***Cow, Sheep, Pig***
-> sc_playRole ***EatenRole***

{ 名 肉，食物，餐 }Noun, Chinese
-> sc_domainOf ***Cow, Sheep, Pig, Rat, Mole, Monkey***
-> sc_playRole ***EatenRole***

{ طعام ,لحم ,غذاء}Noun, Arabic
-> sc_domainOf ***Cow, Sheep***
-> sc_playRole ***EatenRole***

WordNet to Ontology mappings

{07312616} (n) **migration** (the periodic passage of groups of animals (especially birds or fishes) from one region to another for feeding or breeding)

eng-30-07312616-n sc_subClassOf
Kyoto#happening__occurrence__occurrent__natural_event-eng-3.0-07283608-n
eng-30-07312616-n sc_subClassOf
Kyoto#move-eng-3.0-01855606-v

{01857093} (v) **migrate** (move periodically or seasonally) "birds migrate in the Winter"; "The workers migrate to where the crops need harvesting"

eng-30-01857093-v sc_subClassOf
Kyoto#happening__occurrence__occurrent__natural_event-eng-3.0-07283608-n
eng-30-01857093-v sc_subClassOf
Kyoto#move-eng-3.0-01855606-v

{02129007} (adj) **migratory** (used of animals that move seasonally) "migratory birds"

eng-30-02129007-a sc_subClassOf
Kyoto#happening__occurrence__occurrent__natural_event-eng-3.0-07283608-n
eng-30-02129007-a sc_subClassOf
Kyoto#move-eng-3.0-01855606-v

WordNet to Ontology mappings

Kyoto#move-eng-3.0-01855606-v SubClassOf Kyoto#move-eng-3.0-01855606-v inherited

Kyoto#move-eng-3.0-01855606-v SubClassOf Kyoto#change_of_location__movement_11-eng-3.0-00280586-n

Kyoto#move-eng-3.0-01855606-v SubClassOf Kyoto#verb_motion

Kyoto#move-eng-3.0-01855606-v SubClassOf DOLCE-Lite.owl#perdurant inherited

Kyoto#move-eng-3.0-01855606-v merged.owl#pertinent-quality DOLCE-Lite.owl#spatial-location_q inherited

Kyoto#move-eng-3.0-01855606-v SubClassOf Kyoto#change-eng-3.0-00191142-n inherited

Kyoto#move-eng-3.0-01855606-v merged.owl#initial-quality DOLCE-Lite.owl#space-region inherited

Kyoto#move-eng-3.0-01855606-v merged.owl#end-quality DOLCE-Lite.owl#space-region inherited

Kyoto#move-eng-3.0-01855606-v **DOLCE-Lite.owl#participant** DOLCE-Lite.owl#endurant inherited

Kyoto#move-eng-3.0-01855606-v **Kyoto#has-path** DOLCE-Lite.owl#particular inherited

Kyoto#move-eng-3.0-01855606-v **Kyoto#has-source** DOLCE-Lite.owl#particular inherited

Kyoto#move-eng-3.0-01855606-v **Kyoto#has-destination** DOLCE-Lite.owl#particular inherited

Kyoto#move-eng-3.0-01855606-v DOLCE-Lite.owl#has-quality DOLCE-Lite.owl#temporal-location_q inherited

Kyoto#move-eng-3.0-01855606-v SubClassOf DOLCE-Lite.owl#spatio-temporal-particular inherited

Kyoto#move-eng-3.0-01855606-v DOLCE-Lite.owl#has-quality DOLCE-Lite.owl#temporal-quality inherited

Kyoto#move-eng-3.0-01855606-v DOLCE-Lite.owl#part DOLCE-Lite.owl#perdurant inherited

Kyoto#move-eng-3.0-01855606-v SubClassOf DOLCE-Lite.owl#accomplishment inherited

Kyoto#move-eng-3.0-01855606-v DOLCE-Lite.owl#specific-constant-constituent DOLCE-Lite.owl#perdurant inherited

Kyoto#move-eng-3.0-01855606-v SubClassOf DOLCE-Lite.owl#particular inherited

Kyoto#move-eng-3.0-01855606-v SubClassOf DOLCE-Lite.owl#event inherited

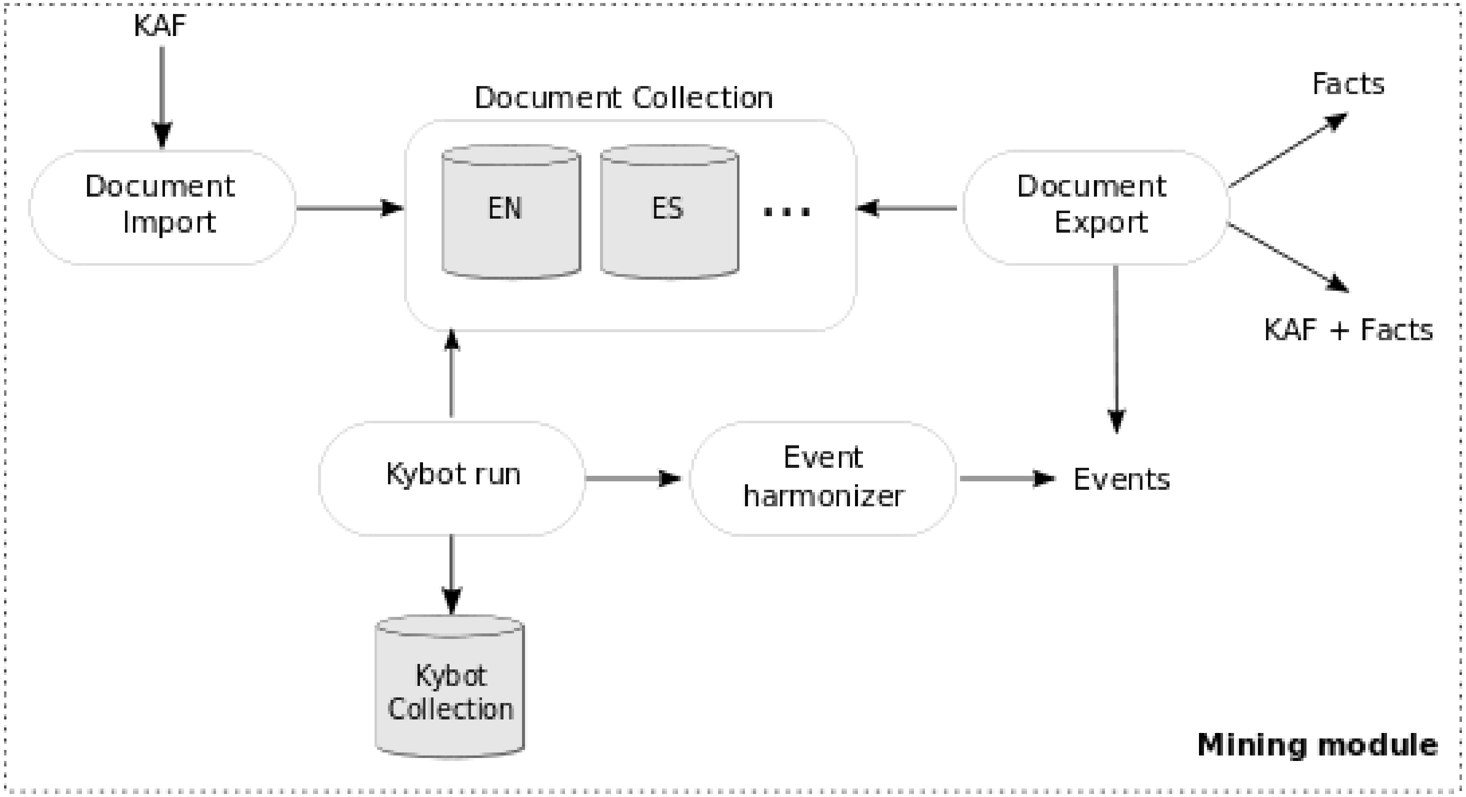
KYOTO Ontology

- **Full** wordnet mappings to the ontology:
  - 114,016 synset-to-base concept mappings
  - 185,666 synset-to-ontology mappings
  - Includes subclass relations and role relations based on the morpho-semantic links in WordNet and the EuroWordNet top-ontology
- Ontology and wordnet mappings provide a huge semantic resource for generic processing
- Using the equivalence relations across wordnets, we can transfer this to the rest of languages!

KYOTO pipelines & WSD service

- English / Italian
  - http://wiki.ilc.cnr.it/kyoto_demo/index.php
- English / Spanish / Basque
  - http://ixa2.si.ehu.es/demokaf/demokaf.pl
- WSD by evocation
  - http://xmlgroup.iit.cnr.it/demos/WSD/

Mining Module Architecture



- KAF (ontotagged) Documents stored in XML DB
- Kybots are stored in XML documents (files)
- Kybots are executed using XQueries on the XML DB

Kybot application

- User uploads documents to the collection
- User applies a series of Kybots to documents
    - Or a subset of docs (ex. only a language)
- Kybots create new events and facts
- Also, keep track of which kybot created which fact

Kybot profiles

- Self descriptive (for manual Kybot creation)
- Pattern-matching like, plus many capabilities.
- Use XML syntax to define the kybots
- Efficient
    - Able to manage thousands of KAF documents

Kybot profiles

- Powerful expressions
- POS
- Lemma
- Senses, Base Concepts
- Ontological references
- Suffix/prefix expressions
- Conjunction, disjunction, optionality
- Negation
- Chunks
- Not in between
- Predicate-filler Kybots

Kybot profiles

```
<?xml version="1.0" encoding="utf-8"?>

<Kybot id="Generate_Pollution">

<variables>
    <var name="X" type="term" pos="N"/>
    <var name="Y" type="term" lemma="release | produce | generate | ! create"/>
    <var name="Y" pos=”V”/>
    <var name="Z" type="term" lemma="*pollution | pollutant | contaminant"/>
</variables>

<relations>
    <root span="X"/>
    <rel span="Y" pivot="X" direction="following"/>
    <rel span="Z" pivot="Y" direction="following"/>
</relations>

<events>
    <event target="$Y/@tid" lemma="$Y/@lemma" pos="$Y/@pos"/>
    <role target="$X/@tid" rtype="source" lemma="$X/@lemma" pos="$X/@pos"/>
    <role target="$Z/@tid" rtype="patient" lemma="$Z/@lemma" pos="$Z/@pos"/>
</events>

</Kybot>
```

Kybot profiles

```
<?xml version="1.0" encoding="utf-8"?>

<Kybot id="Generate_Pollution">

<variables>
    <var name="X" type="term" pos="N"/>
    <var name="Y" type="term" lemma="release | produce | generate | ! create"/>
    <var name="Y" pos=”V”/>
    <var name="Z" type="term" lemma="*pollution | pollutant | contaminant"/>
</variables>

<relations>
    <root span="X"/>
    <rel span="Y" pivot="X" direction="following"/>
    <rel span="Z" pivot="Y" direction="following"/>
</relations>

<events>
    <event target="$Y/@tid" lemma="$Y/@lemma" pos="$Y/@pos"/>
    <role target="$X/@tid" rtype="source" lemma="$X/@lemma" pos="$X/@pos"/>
    <role target="$Z/@tid" rtype="patient" lemma="$Z/@lemma" pos="$Z/@pos"/>
</events>

</Kybot>
```

Variables

Kybot profiles

```
<?xml version="1.0" encoding="utf-8"?>

<Kybot id="Generate_Pollution">

<variables>
    <var name="X" type="term" pos="N"/>
    <var name="Y" type="term" lemma="release | produce | generate | ! create"/>
    <var name="Y" pos=”V”/>
    <var name="Z" type="term" lemma="*pollution | pollutant | contaminant"/>
</variables>

<relations>
    <root span="X"/>
    <rel span="Y" pivot="X" direction="following"/>
    <rel span="Z" pivot="Y" direction="following"/>
</relations>

<events>
    <event target="$Y/@tid" lemma="$Y/@lemma" pos="$Y/@pos"/>
    <role target="$X/@tid" rtype="source" lemma="$X/@lemma" pos="$X/@pos"/>
    <role target="$Z/@tid" rtype="patient" lemma="$Z/@lemma" pos="$Z/@pos"/>
</events>

</Kybot>
```

Relations

Kybot profiles

```
<?xml version="1.0" encoding="utf-8"?>

<Kybot id="Generate_Pollution">

<variables>
    <var name="X" type="term" pos="N"/>
    <var name="Y" type="term" lemma="release | produce | generate | ! create"/>
    <var name="Y" pos=”V”/>
    <var name="Z" type="term" lemma="*pollution | pollutant | contaminant"/>
</variables>

<relations>
    <root span="X"/>
    <rel span="Y" pivot="X" direction="following"/>
    <rel span="Z" pivot="Y" direction="following"/>
</relations>

<events>
    <event target="$Y/@tid" lemma="$Y/@lemma" pos="$Y/@pos"/>
    <role target="$X/@tid" rtype="source" lemma="$X/@lemma" pos="$X/@pos"/>
    <role target="$Z/@tid" rtype="patient" lemma="$Z/@lemma" pos="$Z/@pos"/>
</events>
```

Output Template

```
</Kybot>
```

Kybot profiles: Output

```xml
<kybotOut>
  <doc shortname="1534.mw.wsd.ne.onto.kaf">
    <event target="t886" lemma="generate" pos="V" eid="e1"/>
    <role target="t884" rtype="source" lemma="watershed" .../>
    <role target="t892" rtype="patient" lemma="pollution" .../>
  </doc>
  <doc shortname="17795.mw.wsd.ne.onto.kaf">
    <event target="t9690" lemma="release" pos="V" eid="e1"/>
    <role target="t9691" rtype="patient" lemma="pollutant" .../>
    <role target="t9678" rtype="source" lemma="fuel" .../>
    <role target="t9680" rtype="source" lemma="heating" .../>
    <role target="t9681" rtype="source" lemma="machinery" .../>
    <role target="t9683" rtype="source" lemma="equipment" .../>
    <role target="t9686" rtype="source" lemma="household" .../>
    <role target="t9688" rtype="source" lemma="business" .../>
  </doc>
</kybotOut>
```

Complex profiles

```
<Kybot id="generic_kybot-accomplishment-affectORimpact-physical-endurant">
 <variables>
   <var name="v1" type="term" lemma="! can" reftype="SubClassOf"
          reference="DOLCE-Lite.owl#accomplishment"/>
   <var name="v1" type="term" lemma="! do"/>
   <var name="vnot1" type="term" pos="V | P | D"/>
   <var name="v2" type="term" pos="V" lemma="affect | impact"/>
   <var name="v3" type="term" pos="N" reftype="SubClassOf"
          reference="DOLCE-Lite.owl#physical-endurant"/>
   <var name="vnot2" type="term" pos="V | P"/>
</variables>

 <relations>
   <root span="v3"/>
   <rel span="v1" pivot="v2" direction="preceding" notInBetween="vnot1"/>
   <rel span="v2" pivot="v3" direction="preceding" notInBetween="vnot2"/>
 </relations>

 <events>
   <event target="$v2/@tid"/>
   <role target="$v1/@tid"  rtype="simple-cause-of"/>
   <role target="$v3/@tid" rtype="patient"/></events></Kybot>
```

Kybot profiles: Output (simplified)

```
<kybotOut>
 <doc shortname="11767.mw.wsd.ne.onto.kaf">
  <event eid="e1" target="t779" lemma="impact" pos="V" />
  <role rid="r1" event="e1" target="t778" lemma="pollution" pos="N"
        rtype="simple-cause-of" />
  <role rid="r2" event="e1" target="t782mw" lemma="chesapeake bay" pos="N"
        rtype="patient" />
  <role rid="r3" event="e1" target="t785" lemma="tributary" pos="N"
        rtype="patient" />
  <event eid="e2" target="t1644" lemma="affect" pos="V" />
  <role rid="r4" event="e2" target="t1643" lemma="snowfall" pos="N"
        rtype="simple-cause-of" />
  <role rid="r5" event="e2" target="t1646mw" lemma="water flow" pos="N"
        rtype="patient" />
  <event eid="e3" target="t5045" lemma="affect" pos="V" />
  <role rid="r6" event="e3" target="t5042" lemma="water" pos="N"
        rtype="simple-cause-of" />
  <role rid="r7" event="e3" target="t5048" lemma="level" pos="N"
        rtype="patient" />
 </doc>
</kybotOut>
```

Predicate-filler Kybots: Kybots and Ontology

- Profiles combine syntactic patterns and ontological information
- For example:

X (noun) << Y (verb)
participant-in(event:Y, filler:X)

```
<externalRef reftype="Kyoto#active-participant-in"
             reference="Kyoto#protection-eng-3.0-00817680-n"/>
```

One of the major concerns of the Linconsire's Wildlife Crime Officer is the protection of the estuary habitats.

```
<externalRef reference="Kyoto#protection-eng-3.0-00817680-n"
             reftype="SubclassOf"/>
```

Predicate-filler Kybots

```
<Kybot id="generic_kybot">
  <variables>
    <var name="X" type="term" pos="N"/>
    <var name="Y" type="term" pos="V"/>
  </variables>

  <relations>
    <root span="Y"/>
    <rel span="X" pivot="Y" direction="preceding"/>
    <predicate pred="DOLCE-Lite.owl#participant-in"
               event="Y" filler="X"/>
  </relations>

  <events>
    <event target="$Y/@tid" lemma="$Y/@lemma" pos="$Y/@pos"/>
    <role target="$X/@tid" lemma="$X/@lemma" pos="$X/@pos"
          rtype="participant"/>
  </events>
</Kybot>
```

Kybot output

```
<kybotOut>
 <doc name="11614.mw.wsd.ne.onto.kaf">
  <event eid="e1" target="t1718" lemma="protect" pos="N"/>
  <role rid="r1" event="e1" target="t1715"
        rtype="participant" lemma="crime_officer" pos="N"/>

  ...
 </doc>
</kybotOut>
```

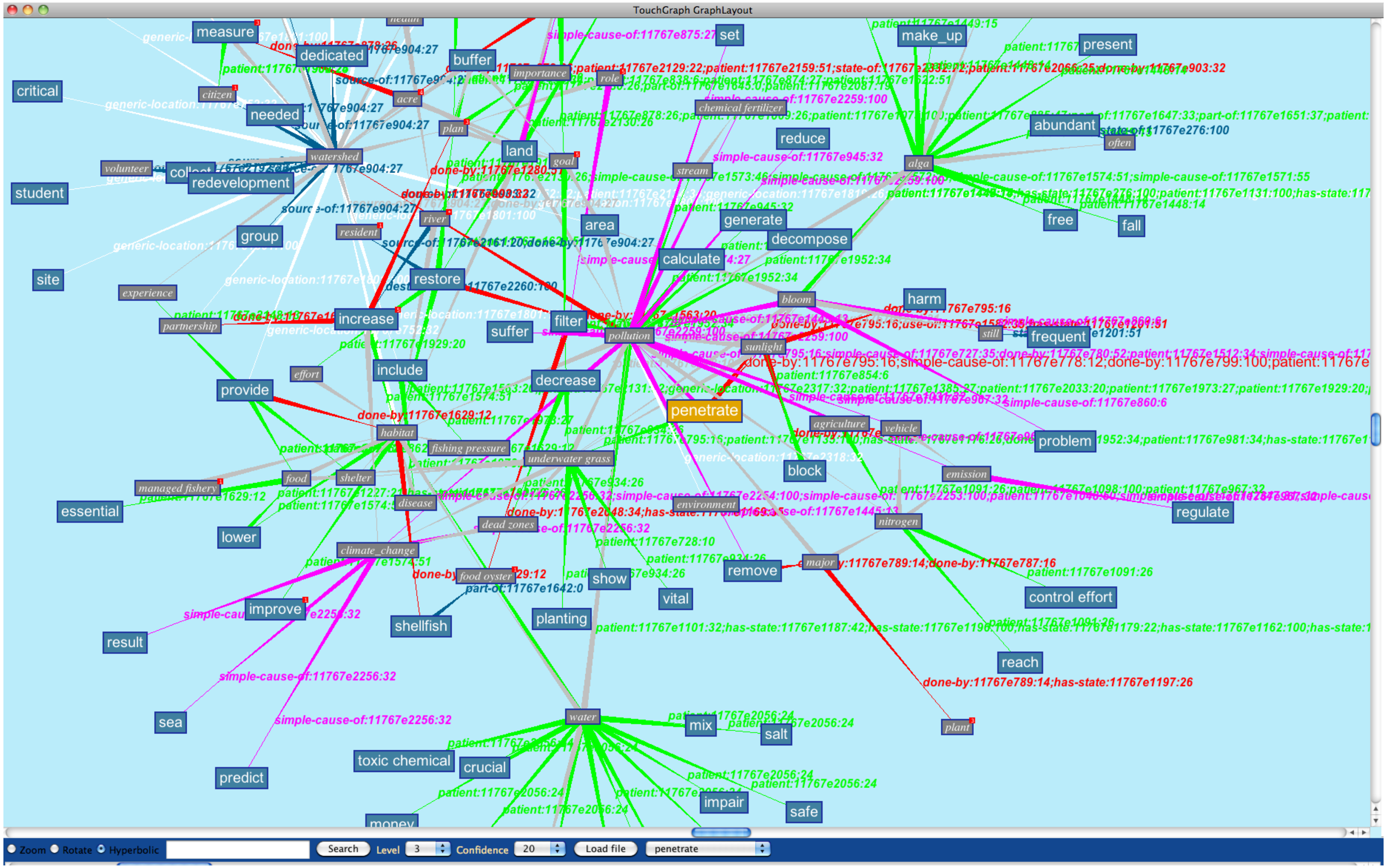
Event Harmonizer

- Group events and facts
  - Refer to same term and synset
- Locate events/roles in space/time
  - NER module: identify locations and dates in documents
  - Apply heuristics to events/roles to associate best location/date

Kybot output with dates/locations

```
 <doc shortname="23452.mw.wsd.ne.onto.kaf">
 <event eid="e1" target="t723" lemma="graze" pos="V"
        synset="eng-30-00669762-v" rank="0.0329727">
   <place countryCode="GB" countryName="United Kingdom" latitude="52.2"
          longitude="-2.6666667" name="Humber" timezone="Europe/London">
     <span id="t721"/>
   </place>
   <dateInfo dateISO="1999" lemma="1999">
     <span id="t527"/>
   </dateInfo>
 </event>
 <role rid="r1" event="e1" target="t731" lemma="outer estuary" pos="N"
       rtype="generic-location" synset="eng-30-09225146-n" rank="0.19" >
  <place ...>...</place>
  <dateInfo ...>...</dateInfo>
</role>
...
</doc>
```

Collecting events/roles



Level 3

Confidence 20

penetrate

Kybot Evaluation & Benchmarking

- Profiles
- Benchmarking
- Project internal evaluation
  - Gold-standard
  - Error analysis
  - Effect of WSD
  - Effect of best profiles
  - Effect of domain modelling
- Open competition
- Transferrring Kybots to another language
- Transferring Kybots to another domain

Profiles

- Currently we have **261** generic profiles
  - Manually developed
  - Search for generic ontological relations
    - “accomplishment affects/impacts accomplishment”
    - “accomplishment of biological-object”
    - …
- Specific profiles for extracting implicit events in compounds
  - “migratory bird” evokes a migration event
  - “crab exploitation” has 'crabs' as patients
  - etc.

Performance

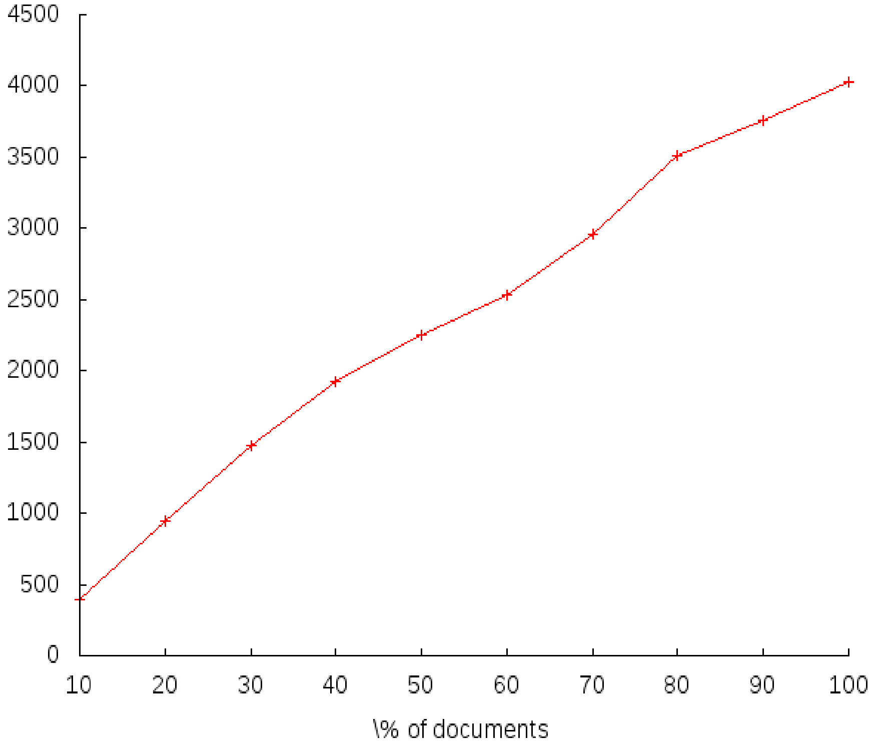
- Running times on medium size and big corpora
    - Subset of 60 profiles
    - Two corpus
        - **Benchmark** corpus
            - 21,721 words
            - 706,646 external references
        - **Estuary** corpus
            - ~3 million terms
            - ~60 million external references

	Benchmark	Estuary
N. events	2,936	185,012
Time	119s	16,112s

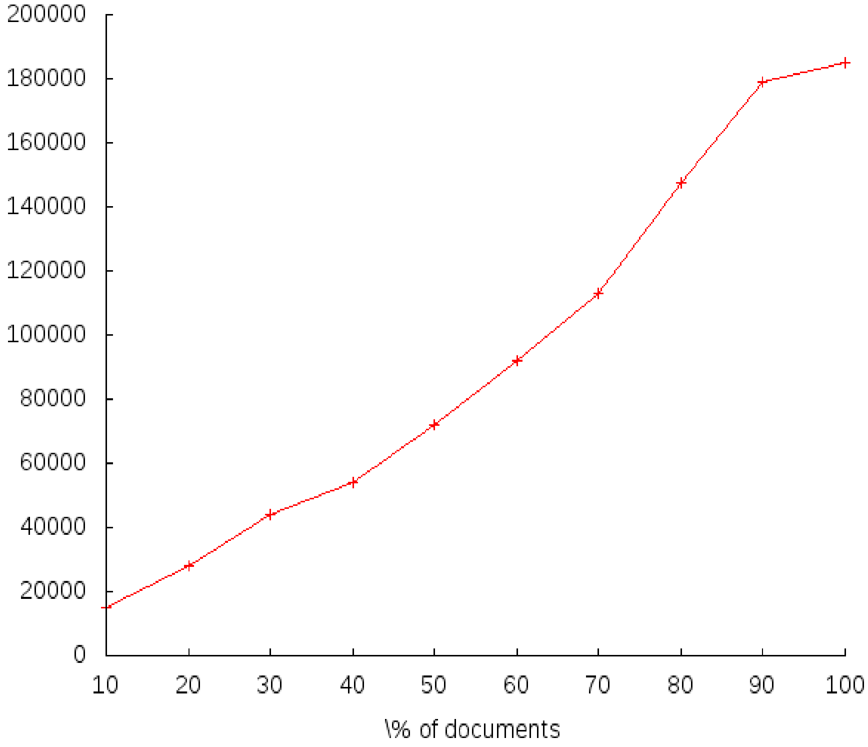
Performance varying corpus size

- Measure performance with different size corpora
- On average, 20 facts per second

Time



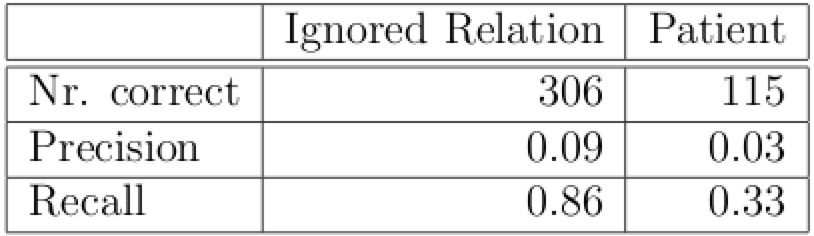
N. of facts



Kybot output evaluation

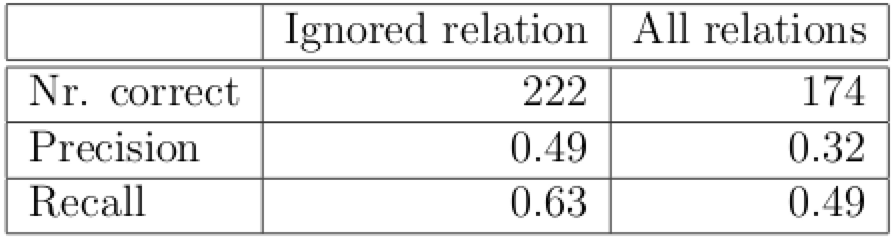
- Create **gold standard**
  - Choose one document: www.acb-online.org/pubs/BayBarometer2008 Web.pdf
  - Manually annotate events/roles
    - Convert events/roles to triplets
    - **KafAnnotator**
    - 127 sentences, 1,416 tokens
    - Annotate 353 triplets (201 unique events)
- Run Kybot profiles and measure precision/recall.

Kybot output evaluation



	Ignored Relation	Patient
Nr. correct	306	115
Precision	0.09	0.03
Recall	0.86	0.33

Table 3: Baseline of chunk heads in the same sentence.



	Ignored relation	All relations
Nr. correct	222	174
Precision	0.49	0.32
Recall	0.63	0.49

Table 4: Generic processing with 261 profiles

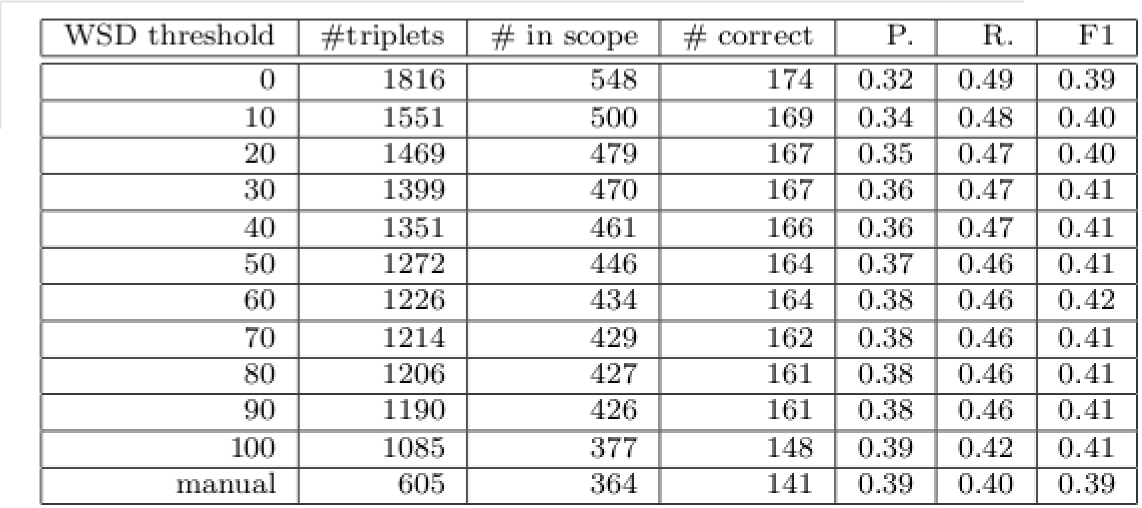
Kybot output evaluation

- **Error Analysis**
  - More / better information from the **parser**
    - POS errors
    - Complex gramatical extructures
    - Compositionality
  - Some annotation errors / discrepancies
  - Some knowledge errors
    - Missing WordNet concepts
    - Wrong ontology class or mapping
  - Missing profiles

Kybot output evaluation

- Effects of **WSD**
  - Excluding low scoring concepts when there is a **choice** (multiple interpretations)
    - event / role
    - different relations

Kybot output evaluation



WSD threshold	#triplets	# in scope	# correct	P.	R.	F1
0	1816	548	174	0.32	0.49	0.39
10	1551	500	169	0.34	0.48	0.40
20	1469	479	167	0.35	0.47	0.40
30	1399	470	167	0.36	0.47	0.41
40	1351	461	166	0.36	0.47	0.41
50	1272	446	164	0.37	0.46	0.41
60	1226	434	164	0.38	0.46	0.42
70	1214	429	162	0.38	0.46	0.41
80	1206	427	161	0.38	0.46	0.41
90	1190	426	161	0.38	0.46	0.41
100	1085	377	148	0.39	0.42	0.41
manual	605	364	141	0.39	0.40	0.39

Table 7: Generic processing with different WSD thresholds.

- Better recall than manual WSD !

Kybot output evaluation

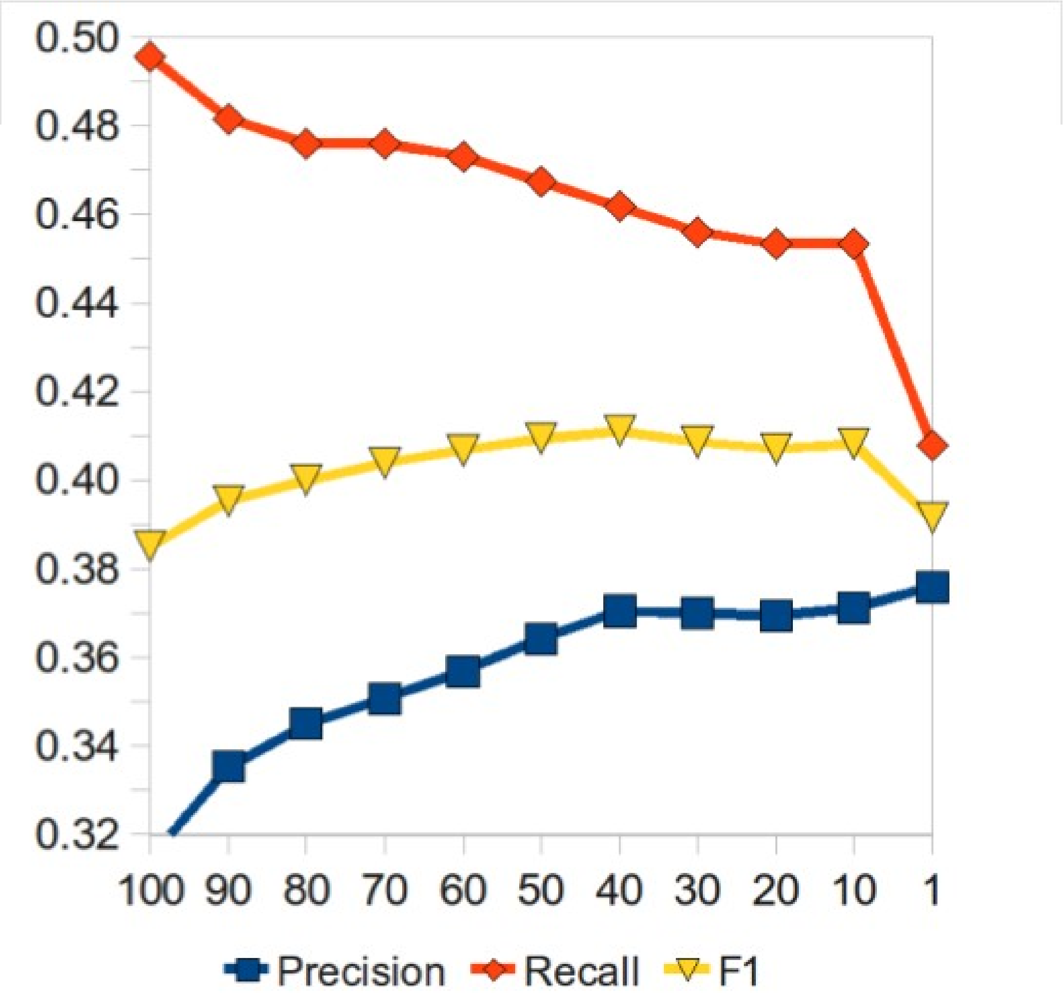
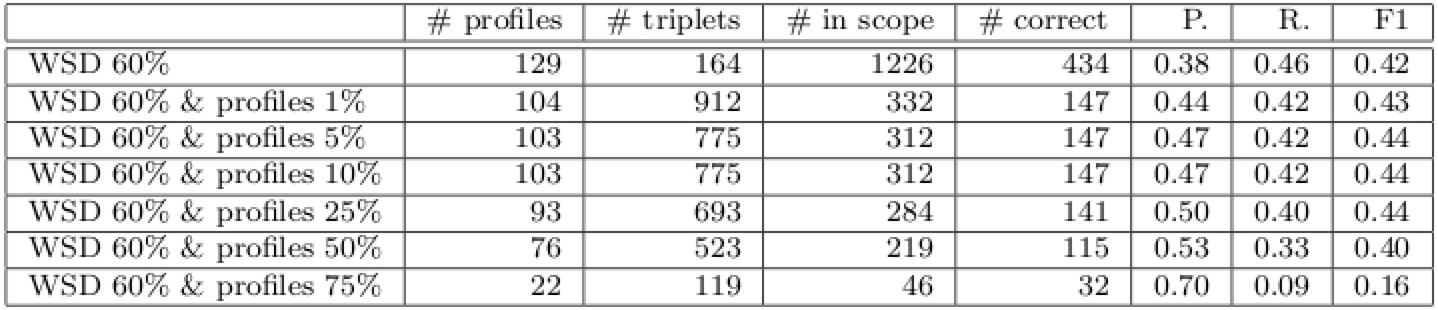


Figure 1: Results when keeping the top $N\%$ word senses according to the WSD scores.

Kybot output evaluation

- **Best performing** profiles



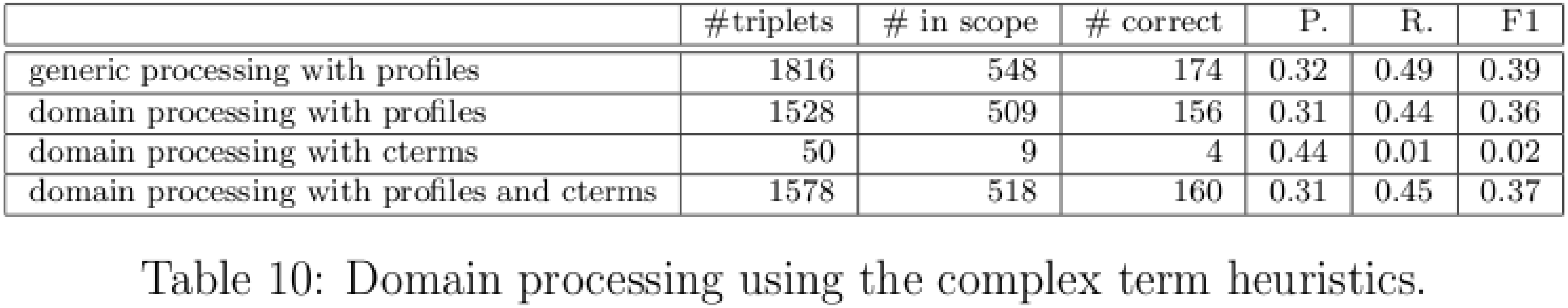
	# profiles	# triplets	# in scope	# correct	P.	R.	F1
WSD 60%	129	164	1226	434	0.38	0.46	0.42
WSD 60% & profiles 1%	104	912	332	147	0.44	0.42	0.43
WSD 60% & profiles 5%	103	775	312	147	0.47	0.42	0.44
WSD 60% & profiles 10%	103	775	312	147	0.47	0.42	0.44
WSD 60% & profiles 25%	93	693	284	141	0.50	0.40	0.44
WSD 60% & profiles 50%	76	523	219	115	0.53	0.33	0.40
WSD 60% & profiles 75%	22	119	46	32	0.70	0.09	0.16

Table 9: Generic processing with WSD threshold of 60% and using best performing profiles.

- Precision 50% vs. 39% manual WSD!
- Improve parsing (and Kybots) instead of better WSD

Kybot output evaluation

- **Generic** vs. **Domain**



	#triplets	# in scope	# correct	P.	R.	F1
generic processing with profiles	1816	548	174	0.32	0.49	0.39
domain processing with profiles	1528	509	156	0.31	0.44	0.36
domain processing with cterms	50	9	4	0.44	0.01	0.02
domain processing with profiles and cterms	1578	518	160	0.31	0.45	0.37

Table 10: Domain processing using the complex term heuristics.

- Generic processing better than domain !
  - Generic: 19,037 links to the ontology in the doc.
  - Domain: 16,953 links to the ontology in the doc.

Kybot output evaluation

- “airborne contaminant” **dw-eng-30-258-n**

  sc_hasState Kyoto#airborne
  sc_partOf DomainKyoto2#air
  sc_subClassOf Kyoto#material__stuff-eng-3.0-14580897-n

- “contaminant” **eng-30-14821984-n**

  sc_domainOf DOLCE-Lite.owl#amount-of-matter
  sc_participantOf Kyoto#change__alter__modify-eng-3.0-00126264-v
  sc_participantOf Kyoto#contamination__pollution-eng-3.0-00276987-n
  sc_playRole Kyoto#done-by
  sc_playRole Kyoto#use-of
  sc_subClassOf Kyoto#material__stuff-eng-3.0-14580897-n

- “airborne” **eng-30-01522895-a**

  sc_qualityOf Kyoto#quality-eng-3.0-04723816-n

Kybot output evaluation

- “suburban runoff” **dw-eng-30-221-n**
  sc_hasCoParticipant Kyoto#city__metropolis-eng-3.0-08524735-n
  sc_playCoRole Kyoto#has-source
  sc_subClassOf Kyoto#happening__natural_event-eng-3.0-07283608-n

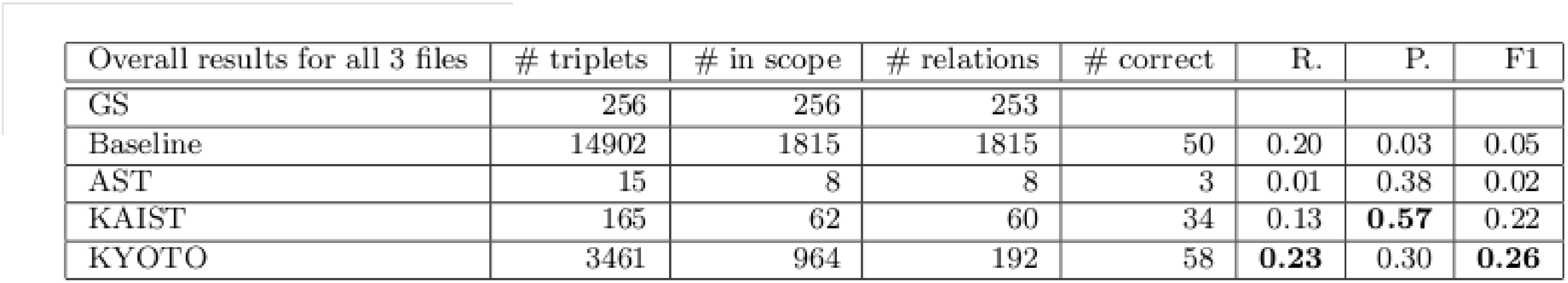
- “runoff” **eng-30-07407272-n**
  sc_domainOf Kyoto#water-eng-3.0-07935504-n
  sc_participantOf Kyoto#flow
  sc_playRole Kyoto#done-by
  sc_subClassOf Kyoto#commerce__mercantilism-eng-3.0-01090446-n
  sc_subClassOf Kyoto#happening__natural_event-eng-3.0-07283608-n
  sc_subClassOf Kyoto#move-eng-3.0-01831531-v

- “suburban” **eng-30-02804590-a**
  sc_qualityOf Kyoto#district__territory__dominion-eng-3.0-08552138-n
  sc_subClassOf Kyoto#quality-eng-3.0-04723816-n

Open competition

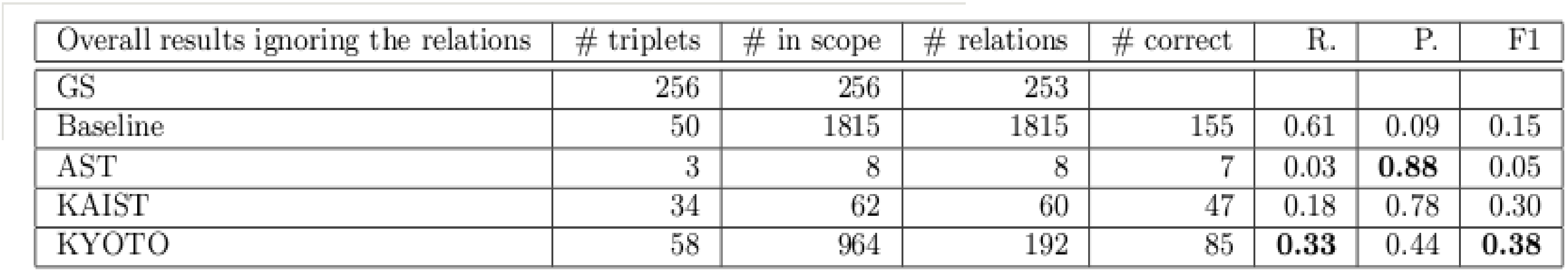
- Create **gold standard**
  - Choose three documents: http://www.thedailygreen.com
  - Manually annotate events/roles
    - Convert events/roles to triplets
    - **KafAnnotator**
    - 2,003 tokens
    - Annotate 256 triplets
- Run Kybot profiles and measure precision/recall.

Results Open Competition



Overall results for all 3 files	# triplets	# in scope	# relations	# correct	R.	P.	F1
GS	256	256	253				
Baseline	14902	1815	1815	50	0.20	0.03	0.05
AST	15	8	8	3	0.01	0.38	0.02
KAIST	165	62	60	34	0.13	**0.57**	0.22
KYOTO	3461	964	192	58	**0.23**	0.30	**0.26**

Table 12: Results of the open competition.



Overall results ignoring the relations	# triplets	# in scope	# relations	# correct	R.	P.	F1
GS	256	256	253				
Baseline	50	1815	1815	155	0.61	0.09	0.15
AST	3	8	8	7	0.03	**0.88**	0.05
KAIST	34	62	60	47	0.18	0.78	0.30
KYOTO	58	964	192	85	**0.33**	0.44	**0.38**

Table 14: Results of the open competition, ignoring the relation

Transferring Kybots to another language

- Estuary database (**Dutch**)
- 93 documents, 42,697 words.

- 65 Dutch profiles adapted from English (**half a day work**)

- 4,095 events
- 6,862 roles
- 8,118 date expressions, 82 unique dates
- 5,928 place expressions, 60 unique GeoNames places
- 3,302 countries, 9 unique GeoNames countries

Transferring Kybots to another domain

- Medical protocols on the **treatment of breast cancer**
- 7 PDF documents, 110,501 word tokens
- No domain adaptation

- 8,416 events
- 15,984 roles
- Examples:
  - "disease includes tumour" ...
  - "axilla contains a sentinel lymph node"
  - "a side effect risk is part of the treatment"

Main results so far

- **KAF**
- **Generic Knowledge Architecture**
  - 3-layered model
  - Kyoto ontology
  - Formal mapping to **all** wordnets synsets
- **Robust Ontology-based IE**
  - Kybot, mining module
  - Off-line reasoning
  - Portable to other languages
  - Portable to other domains
- **Evaluation framework**

Current and future plans

- Chunk level queries
  - Search for a term and then a chunk whose head is ...
  - Inter-chunk searches
    - Search for a term and then, in the same chunk, another one which ...
- Dependency queries
- Layer-2 Kybots
  - Amalgamate events from several documents and languages
- Creating Kybots semi or fully automatically
  - Mining by example
  - Machine learning / Active Learning

KYOTO (ICT-211423) Intelligent Content and Semantics
Knowledge **Y**ielding **O**ntologies for **T**ransition-Based **O**rganization
http://www.kyoto-project.eu/

Event and Fact Mining

German Rigau
IXA group, UPV/EHU

Final Review
April 8th, 2011, Berlin, Germany