A 2-Phase Frame-based Knowledge Extraction Framework

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http://pikes.fbk.eu/
Problem

Knowledge Extraction from Text
- English text only
- ABox (instances and facts) only → Ontology Population
- focus on extracting events and their participants
  → represented as semantic frames, i.e., event instances (e.g. ‘sell’ event) linked to participant instances via role properties (e.g. ‘seller’)

Example: “G. W. Bush and Bono are very strong supporters of the fight of HIV in Africa.”
Contribution

PIKES* ▲
- a tool for Knowledge Extraction from English text
- extracting semantic frames
  - aligned to predicate models
    → PropBank (PB), NomBank (NB), VerbNet (VN), FrameNet (FN)
  - **new**: aligned to FrameBase
- extracting instances
  - typed w.r.t. YAGO and SUMO
  - disambiguated w.r.t. DBpedia
- representing all contents in RDF + named graph
- based on a 2-phase approach
- open source – http://pikes.fbk.eu/

(*) PIKES is a Knowledge Extraction Suite
Corcoglioniti et al. KnowledgeStore: a storage framework for interlinking unstructured and structured knowledge. IJSWIS 2015
Complete model:

```
nif: <http://persistence.uni-leipzig.org/nlp2rdf/ontologies/nif-core#>
ks: <http://dkm.fbk.eu/ontologies/knowledgestore#>
foaf: <http://xmlns.com/foaf/0.1/>
```

**Instance layer**

- **ks:Instance**
  - rdf:type
  - rdfs:label
  - foaf:name
  - owl:sameAs
  - rdfs:seeAlso
  - ks:include
  - frame/arg rel.

**Mention layer**

- **ks:RelationMention**
  - ks:coreferentialConjunct

- **ks:CoreferenceMention**
  - ks:coreferential

- **ks:RelationMention**
  - ks:argument

- **ks:CoreferenceMention**
  - ks:target

- **ks:FrameMention**
  - ks:predicate

- **ks:PredicateMention**
  - ks:role

- **ks:AttributeMention**
  - ks:normalizedValue

- **ks:TimeMention**
  - ks:norm.Value

**Resource layer**

- **ks:Resource**
  - dct:title
  - dct:creator
  - dct:created

- **ks:RelationMention**
  - ks:mentionOf

- **ks:Attribute**
  - ks:include

- **ks:Frame**
  - owl:sameAs

- **ks:Time**
  - OWL time props.

- **Assertion (graph)**
  - contains triples about

---

A 2-phase Frame-based Knowledge Extraction Framework - Corcoglioniti, Rospocher, Palmero Aprosio
2-Phase Approach

Resource layer

G. W. Bush and Bono are very strong supporters of the fight of HIV in Africa.

Mention layer

Phase 1
Linguistic Feature Extraction

Phase 2
Knowledge Distillation

Instance layer
Linguistic Feature Extraction

① apply several NLP tasks to input text
② map their outputs to mentions

<table>
<thead>
<tr>
<th>NLP Task</th>
<th>Type of mention</th>
<th>Instance</th>
<th>Name</th>
<th>Time</th>
<th>Attribute</th>
<th>Frame</th>
<th>Participation</th>
<th>Coreference</th>
</tr>
</thead>
<tbody>
<tr>
<td>part-of-speech tagging</td>
<td>POS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>named entity recognition &amp; classification</td>
<td>NERC</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>temporal expression recognition &amp; norm.</td>
<td>TERN</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>entity linking</td>
<td>EL</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>word sense disambiguation</td>
<td>WSD</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>semantic role labeling</td>
<td>SRL</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>coreference resolution</td>
<td>COREF</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dependency parsing</td>
<td>DP</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example:

“fight of HIV”

via NERC, EL

via SRL

via SRL, DP

Extracted RDF mention graph

<..#char=63,66> a :NameMention ;
  nif:anchorOf “HIV” ;
  :nercType :MISC ;
  :linkedTo dbpedia:HIV .

<..#char=54,59> a :FrameMention ;
  nif:anchorOf “fight”
  :predicate pm:nb10-fight.01 .

<..#char=54,66> a :ParticipationMention;
  nif:anchorOf “fight […] HIV”
  :frame <..#char=54,59> ;
  :argument <..#char=63,66> ;
  :role pmo:nb10-fight.01-arg1 .
Knowledge Distillation

① Rule-based conversion from Mention to Instance data
- deal with phenomena such as argument nominalization and group entities
- use background knowledge
  → e.g., mappings to ontologies, characterization of predicates

② Post-processing: OWL2RL inference, reduce # of named graphs

**Mention layer**

:mention1 a ks:FrameMention;
nif:anchorOf "supporters";
ks:synset wn30:n-10677713;
ks:predicate pmo:nb10_support.01;
ks:role pmo:nb10_support.01_arg01;

**Instance layer**

:g1 { :e1 a dbyago:Supporter110677713.  
  :ev1 a frb:frame-taking_sides;  
  frb:fe-taking_sides-cognizer :e1. }

:mention1 ks:expresses :g1;  
ks:denotes :e1; ks:implies :ev1.

**Background knowledge**

pmo:nb10_support.01 a ks:ArgumentNominalization.
Knowledge Distillation (2)

Longer example:

**Mention layer**

:m1 a ks:NameMention;
  nif:anchorOf "G. W. Bush";
  ks:nercType ks:bbn_person.

:m2 a ks:NameMention;
  nif:anchorOf "Bono";
  ks:nercType ks:bbn_person.

:m3 a ks:FrameMention;
  nif:anchorOf "supporters";
  ks:predicate pmo:nb10_support.01;
  ks:role pmo:nb10_support.01_arg01;

:m4 a ks:CoreferenceMention;
  ks:coreferential :m3;
  ks:coreferentialConjunct :m1, m2.

**Instance layer**

:m1 ks:expresses :g1; ks:denotes :e1 .
  :g1 { :e1 a dbyago:PersonXYZ;
        owl:sameAs dbpedia:Bush;
        foaf:name "G. W. Bush". }

:m2 ks:expresses :g2; ks:denotes :e2 .
  :g2 { :e2 a dbyago:PersonXYZ;
        owl:sameAs dbpedia:Bono;
        foaf:name "Bono". }

:m3 ks:expresses :g3; ks:denotes :e3;
  ks:implies :ev1.
  :g3 { :e3 a dbyago:SupporterXYZ.
        :ev1 a frb:frame-taking_sides;
        frb:fe-taking_sides-cognizer :e3. }

:m4 ks:expresses :g4.
  :g4 { :e3 ks:include :e1, :e2 }

**Background knowledge**

pmo:nb10_support.01
  a ks:ArgumentNominalization.
Knowledge Distillation (3)

Post-processing:
- RDFS / OWL2RL inference & owl:sameAs smushing
- propagate triples from group entities to their members
- optimize use of named graphs

Instance layer (before)

:\[ g_1 \{ :e1 a dbyago:PersonXYZ; \]
\[ \text{owl:sameAs dbpedia:Bush.} \} \]
\[ g_2 \{ :e2 a dbyago:PersonXYZ; \]
\[ \text{owl:sameAs dbpedia:Bono.} \} \]
\[ g_3 \{ :e3 a dbyago:SupporterXYZ. \]
\[ :ev1 a frb:frame-taking_sides; \]
\[ \text{frb:fe-taking_sides-cognizer :e3.} \} \]
\[ g_4 \{ :e3 ks:include :e1, :e2 \} \]
\[ :m1 ks:expresses :g1; ks:denotes :e1 \text{. # bush}\]
\[ :m2 ks:expresses :g2; ks:denotes :e2 \text{. # bono}\]
\[ :m3 ks:expresses :g3; ks:denotes :e3; \]
\[ \text{ks:implies :ev1. # supporters}\]
\[ :m4 ks:expresses :g4. \text{ # bush+bono = supporters}\]

Instance layer (post-processed)

:\[ g_1 \{ \text{dbpedia:Bush a dbyago:PersonXYZ, ...} \} \]
\[ g_2 \{ \text{dbpedia:Bono a dbyago:PersonXYZ; ...} \} \]
\[ g_3 \{ :ev1 a frb:frame-taking_sides, ... \} \]
\[ g_4 \{ :ev1 frb:fe-taking_sides-cognizer \]
\[ \text{dbpedia:Bush, dbpedia:Bono }\}
\[ :m1 ks:expresses :g1; ks:denotes \text{dbpedia:Bush.}\]
\[ :m2 ks:expresses :g2; ks:denotes \text{dbpedia:Bono.}\]
\[ :m3 ks:expresses :g3, :g4; ks:implies :ev1; \]
\[ \text{ks:denotes dbpedia:Bush, dbpedia:Bono.}\]
\[ :m4 ks:expresses :g4. \]

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Implementation

PIKES
- Java 1.8 on Linux / Mac OS X
- open source (GPL)
- Maven project on GitHub https://github.com/dkmfbk/pikes

Integrated dependencies
- Stanford CoreNLP
- Mate-tools
- Semafor
- RDFpro

External dependencies
- Dbpedia Spotlight
- UKB

→ need separate install

Phase 1: Linguistic Feature Extraction
- Stanford CoreNLP (tokenization, POS-tagging, lemmatization, NERC, TERN, DP, coref. resolution)
- DBpedia Spotlight (EL)
- Mate (SRL PB/NB)
- Semafor (SRL FrameNet)
- UKB (WSD)

Phase 2: Knowledge Distillation
- Mapping Rule Evaluator (rdfpro)
- Mapping rules
- Mapping triples
- Knowledge graph

Frontend
- Web UI
- ReST API

Input text
- Linguistic annotations
- Mention Extractor
- Mention graph
- Decoupling
- Post processor (rdfpro)
Implementation (2)

PIKES UI for:
“G.W. Bush and Bono are very strong supporters of the fight of HIV in Africa. Their March 2002 meeting resulted in a 5 billion dollar aid.”

http://pikes.fbk.eu/
Implementation (3)

PIKES UI for:
“G.W. Bush and Bono are very strong supporters of the fight of HIV in Africa. Their March 2002 meeting resulted in a 5 billion dollar aid.”

http://pikes.fbk.eu/
Implementation (4)

PIKES UI for:
“G.W. Bush and Bono are very strong supporters of the fight of HIV in Africa. Their March 2002 meeting resulted in a 5 billion dollar aid.”

http://pikes.fbk.eu/
Evaluation

Three evaluations:

① PIKES precision/recall on gold standard

② PIKES vs FRED precision/recall on simpler gold standard

③ PIKES throughput (and sampled precision) on large corpus
Gold Standard


S1 The lone Syrian rebel group with an explicit stamp of approval from Al Qaeda has become one of the uprising most effective fighting forces, posing a stark challenge to the United States and other countries that want to support the rebels but not Islamic extremists.

S2 Money flows to the group, the Nusra Front, from like-minded donors abroad.

S3 Its fighters, a small minority of the rebels, have the boldness and skill to storm fortified positions and lead other battalions to capture military bases and oil fields.

S4 As their successes mount, they gather more weapons and attract more fighters.

S5 The group is a direct offshoot of Al Qaeda in Iraq, Iraqi officials and former Iraqi insurgents say, which has contributed veteran fighters and weapons.

S6 “This is just a simple way of returning the favor to our Syrian brothers that fought with us on the lands of Iraq,” said a veteran of Al Qaeda in Iraq, who said he helped lead the Nusra Front’s efforts in Syria.

S7 The United States, sensing that time may be running out for Syria president Bashar al-Assad, hopes to isolate the group to prevent it from inheriting Syria.

S8 As the United States pushes the Syrian opposition to organize a viable alternative government, it plans to blacklist the Nusra Front as a terrorist organization, making it illegal for Americans to have financial dealings with the group and prompting similar sanctions from Europe.
Gold Standard (2)

Gold knowledge graph
- built manually by 2 annotators
- built sentence by sentence

137 instances
- entities or semantic frames (e.g., events)
- coreferring mentions → distinct instances + owl:sameAs links

166 triples
- frame types and roles based on VN, FN, PB, NB
- owl:sameAs between instances (COREF) and w.r.t. DBpedia (EL)

155 edges
- i.e., unlabeled instance-instance relations
Evaluation Methodology

① Align TBoxes
- tools and gold standard use different VN/FN/PB/NB URIs

② Align instances
- maximize # common triples
- leverage groundings to mentions

③ Compare tool graph $G_T$ and gold graph $G_G$
- for different components: instances, edges, triples (of specific kind)
- *true positives*: items in $G_T$ and $G_G$
- *false negatives*: items in $G_G$ but not $G_T$
- *false positives*: items in $G_T$ but not in $G_G$
  - ignore irrelevant elements in $G_T$ (manual operation)

④ Compute Precision (P), Recall (R), F1
### PIKES against Gold Standard

<table>
<thead>
<tr>
<th>Metric</th>
<th>Precision</th>
<th>Recall</th>
<th>F1</th>
</tr>
</thead>
<tbody>
<tr>
<td>instances</td>
<td>0.943</td>
<td></td>
<td></td>
</tr>
<tr>
<td>edges</td>
<td>0.891</td>
<td></td>
<td></td>
</tr>
<tr>
<td>triples</td>
<td>0.713</td>
<td></td>
<td></td>
</tr>
<tr>
<td>types (VN)</td>
<td>0.706</td>
<td></td>
<td></td>
</tr>
<tr>
<td>types (FN)</td>
<td>0.731</td>
<td></td>
<td></td>
</tr>
<tr>
<td>types (PB)</td>
<td>0.844</td>
<td></td>
<td></td>
</tr>
<tr>
<td>types (NB)</td>
<td>0.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>roles (VN)</td>
<td>0.742</td>
<td></td>
<td></td>
</tr>
<tr>
<td>roles (FN)</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>roles (PB)</td>
<td>0.829</td>
<td></td>
<td></td>
</tr>
<tr>
<td>roles (NB)</td>
<td>0.627</td>
<td></td>
<td></td>
</tr>
<tr>
<td>linking</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>coreference</td>
<td>0.714</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Better than VN/FN types:
- Graph nodes
- Unlabelled edges
- Labelled edges

Better than VN/FN roles:
- Better than VN/FN types
PIKES compared to FRED (1)

FRED: Presutti, V., Draicchio, F., and Gangemi, A. Knowledge extraction based on discourse representation theory and linguistic frames. EKAW 2012

Comparison possible only on restricted gold standard
- no PB / NB frame types
- no PB / NB / FN* frame roles (* marked as :fe by FRED)
- nominal frames converted to binary relations

i.e., for “Iraqi official”

Gold standard / PIKES

FRED
## PIKES compared to FRED (2)

<table>
<thead>
<tr>
<th>Category</th>
<th>PIKES</th>
<th>FRED</th>
<th>PIKES Compared to FRED (F1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>instances</td>
<td>0.937</td>
<td>0.869</td>
<td>+0.059</td>
</tr>
<tr>
<td>edges</td>
<td>0.937</td>
<td>0.768</td>
<td>+0.167</td>
</tr>
<tr>
<td>triples</td>
<td>0.713</td>
<td>0.555</td>
<td>+0.153</td>
</tr>
<tr>
<td>types (VN)</td>
<td>0.667</td>
<td>0.581</td>
<td></td>
</tr>
<tr>
<td>types (FN)</td>
<td>0.543</td>
<td>0.416</td>
<td></td>
</tr>
<tr>
<td>roles (VN)</td>
<td>0.722</td>
<td>0.516</td>
<td></td>
</tr>
<tr>
<td>linking</td>
<td>0.7</td>
<td>0.382</td>
<td></td>
</tr>
<tr>
<td>coreference</td>
<td>0.714</td>
<td>0.516</td>
<td></td>
</tr>
</tbody>
</table>

PIKES exhibits better precision, recall and F1 for all types of triples.
Evaluation on Large Corpus

Corpus: Simple English Wikipedia (dump date: April 6, 2015)

Server
- dual Xeon E5-2430 (24 cores)
- 192GB RAM
- 480GB SSD

Setup
- 16 PIKES instances
- 1 core, 7GB RAM each
- parallel page processing

Processing time
- 32 hours total
- 507 core hours

<table>
<thead>
<tr>
<th>Item</th>
<th># items</th>
<th>Throughput [item/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Documents</td>
<td>109,242</td>
<td>3,450</td>
</tr>
<tr>
<td>Sentences</td>
<td>1,584,406</td>
<td>50,000</td>
</tr>
<tr>
<td>Tokens</td>
<td>23,877,597</td>
<td>753,000</td>
</tr>
</tbody>
</table>

(*) Estimated based on time measured using 16 cores, to provide a normalized throughput value
Evaluation on Large Corpus (2)

Knowledge Extraction results

- ~358M triples total
  → 2M resource layer, 283M mention layer, 72M instance layer
- more than 4M frame instances created
  → most frequent: use.01, play.01, know.01

<table>
<thead>
<tr>
<th>Instance type</th>
<th># Instances</th>
<th># Triples</th>
</tr>
</thead>
<tbody>
<tr>
<td>linked to DBpedia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persons</td>
<td>(1) 72K</td>
<td>19K</td>
</tr>
<tr>
<td>Organizations</td>
<td></td>
<td>49K</td>
</tr>
<tr>
<td>Locations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>not linked to DBpedia</td>
<td>470K</td>
<td>173K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18K</td>
</tr>
<tr>
<td>all</td>
<td>542K</td>
<td>192K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>67K</td>
</tr>
</tbody>
</table>

(1) most frequent: Pope, Jesus, Napoleon
(2) 1.7M annotations, 2.6M types, 21M participations (7M distinct frame-argument pairs)
### Evaluation on Large Corpus (3)

<table>
<thead>
<tr>
<th>Type of triple</th>
<th># Triples</th>
<th>Sampled precision (by evaluator)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ev. 1</td>
<td>Ev. 2</td>
<td>Ev. 3</td>
<td>Avg.</td>
</tr>
<tr>
<td>Annotation</td>
<td>35</td>
<td>0.900</td>
<td>0.886</td>
<td>0.857</td>
<td>0.881</td>
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<tr>
<td>Type</td>
<td>35</td>
<td>0.943</td>
<td>0.771</td>
<td>0.857</td>
<td>0.857</td>
</tr>
<tr>
<td>PB/NB participation</td>
<td>130</td>
<td>0.904</td>
<td>0.785</td>
<td>0.850</td>
<td>0.846</td>
</tr>
<tr>
<td>All</td>
<td>200</td>
<td>0.910</td>
<td>0.800</td>
<td>0.853</td>
<td>0.854</td>
</tr>
</tbody>
</table>

**Methodology**
- sample 200 triples DBpedia instances with 1 mention each
- ask evaluators whether each triple is correct for its mention
  - 1=correct, 0=not correct, 0.5=only predicate is wrong

Fleiss’ kappa coefficient $k = 0.372$

Mapping $0.5 \rightarrow 0$: precision=$0.823$, $k = 0.407$
Conclusions

PIKES is
- a tool for Knowledge Extraction from English text
- extracting events and complex relations (semantic frames)
- representing all contents in RDF + named graph
- based on a 2-phase approach
  - linguistic feature extraction (via state-of-the-art NLP tools)
  - knowledge distillation (rule-based)

Benefits
- competitive with state of the art in terms of quality / throughput
- 2-phase decoupling allows to tune the two phases independently

Future work
- integrate other NLP tasks and PreMOn – http://premon.fbk.eu/
- use PIKES for IR – KE4IR paper @ ESWC2016 – http://pikes.fbk.eu/ke4ir
- detect and repair inconsistencies in PIKES output (via ILP)

Linguistic Linked Data resource (grounded in Lemon) representing **predicate models** and **mapping** resources: PB, NB, VN, FN, Semlink.

Homogeneously represents the **semantic classes** (e.g., rolesets in NB and PB, verb classes in VN, frames in FN) and **semantic roles**.

**Benefits:**
- ease of **access** and **reuse** of predicate model data
- abstract **commonalities**, keep **peculiarities**
- automated **reasoning** and **SPARQL** querying
- **SRL annotations** of a text according NIF
- **interlinking** with third-party datasets

**Availability:** download / SPARQL endpoint / URI dereferencing
KE4IR = Knowledge Extraction for Information Retrieval
http://pikes.fbk.eu/ke4ir

PIKES analysis of query and documents to improve IR performances

Semantics considered (e.g. ``astronomers influenced by Gauss’’)
- URIs: dbpedia:Carl_Friedrich_Gauss
- TYPE: dbyago:Astronomer109818343, dbyago:GermanMathematicians
- FRAME: framebase:Subjective_influence
- TIME: dbo:dateOfBirth (1777), dbo:dateOfDeath (1855)

Performances (on a IR dataset for SW: 331 documents / 35 queries):

<table>
<thead>
<tr>
<th>Approach/System</th>
<th>Prec@1</th>
<th>Prec@5</th>
<th>Prec@10</th>
<th>NDCG</th>
<th>NDCG@10</th>
<th>MAP</th>
<th>MAP@10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google</td>
<td>0.543</td>
<td>0.411</td>
<td>0.343</td>
<td>0.434</td>
<td>0.405</td>
<td>0.255</td>
<td>0.219</td>
</tr>
<tr>
<td>Textual</td>
<td>0.943</td>
<td>0.669</td>
<td>0.453</td>
<td>0.832</td>
<td>0.782</td>
<td>0.733</td>
<td>0.681</td>
</tr>
<tr>
<td>KE4IR</td>
<td>0.971</td>
<td>0.680</td>
<td>0.474</td>
<td>0.854</td>
<td>0.806</td>
<td>0.758</td>
<td>0.713</td>
</tr>
<tr>
<td>KE4IR vs. Textual</td>
<td>3.03%</td>
<td>1.71%</td>
<td>4.55%</td>
<td>2.64%</td>
<td>2.99%</td>
<td>3.50%</td>
<td>4.74%</td>
</tr>
<tr>
<td>p-value (paired t-test)</td>
<td>0.324</td>
<td>0.160</td>
<td>0.070</td>
<td>0.003</td>
<td>0.015</td>
<td>0.024</td>
<td>0.029</td>
</tr>
<tr>
<td>p-value (approx. random.)</td>
<td>1.000</td>
<td>0.496</td>
<td>0.111</td>
<td>0.003</td>
<td>0.020</td>
<td>0.020</td>
<td>0.030</td>
</tr>
</tbody>
</table>
Thank you! Questions?

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SAC 2016
PISA, 06 April 2016

http://pikes.fbk.eu/