Name that sculpture

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Problem statement

- Identify the sculptor and sculpture from an image
- Do it instantly

Motivation:
- Often unlabelled in public spaces
- Unlabelled in other people’s images
- Unlabelled in our own photos and we forgot the name

Sculptor: Giambologna
Sculpture: Hercules and the Centaur Eurytion
Right here in Hong Kong, so we know:

Sculptor: Henry Moore
Sculpture: Oval with Points
Right here in Hong Kong, so we know:
  Sculptor: Henry Moore
  Sculpture: Oval with Points

We recognize the style:
  Sculptor: Henry Moore
  Sculpture: ????????????
Right here in Hong Kong, so we know:
Sculptor:  Henry Moore
Sculpture:  Oval with Points

We recognize the style:
Sculptor:  Henry Moore
Sculpture:  ????????????
Challenging problem

- Large variation in the visual appearance of sculptures
- Not much clean annotation is available
Challenging problem

Recognition disciplines that work and do not work

Hartmut Neven
(Head of Visual Search at Google)

ICML 2011
Multimedia approach

Sculptor: Giambologna
Sculpture: Hercules and the Centaur Eurytion

Image corpus with meta data

Visual matching

Labelling

Matching set with meta data
Sculptor: Giambologna
Sculpture: Hercules and the Centaur Eurytion
Image corpus: Sculptures 50k

- List of prominent sculptors obtained from Wikipedia (616 names)
- 50k images downloaded from Flickr using the list of sculptors
- Meta data: description, title (supplied by the Flickr user)
Visual matching

Sculptor: Giambologna
Sculpture: Hercules and the Centaur Eurytion

Image corpus with meta data

Visual matching

Labelling

Matching set with meta data
Bag-of-Words for textured object retrieval

query image

Hessian-Affine regions + SIFT descriptors [Lowe04, Mikolajczyk07]

Set of SIFT descriptors

visual words

sparse frequency vector

Inverted file

tf-idf weighting

querying

ranked image short-list

Geometric verification [Lowe04, Philbin07]
Bag-of-Words for textured object retrieval

- Query image
- Hessian-Affine regions + SIFT descriptors
- Set of SIFT descriptors
- Visual words
- Sparse frequency vector
- Inverted file
- Querying
- Ranked image short-list
- Results
- 1
- 2
- 3
- 4
- 5
- 6

[References: Lowe04, Mikolajczyk07, Sivic03, Lowe04, Philbin07]
Visual matching

- Bag-of-Words (BoW) works well for textured objects:

- BoW cannot handle smooth (textureless) objects

- Also use the recent Bag-of-Boundaries (BoB) method for smooth object retrieval [Arandjelovic11]
These sculptures are considered equivalent

- Same shape
- Different instances
- Different materials
- Different sizes
Sculptures are defined by shape

- Represent the object shape – use boundaries as proxy for this
- There are too many boundaries (edges) in a cluttered image
  - Perform automatic segmentation
Sculpture segmentation

- Segment sculpture materials: marble, bronze, brass, stone..

- Learn to segment super-pixels from these materials from background

- Features:
  - median gradient magnitude
  - colour
  - texture
  - position within image

- Classification:
  - Linear SVM
Sculpture segmentation
For regularly sampled boundary points (internal and external) compute the descriptor at 3 scales.

Scales are relative to segmentation area.

Gives partial invariance to scale and segmentation failures.
Boundary descriptor:

- HOG (on foreground edges)
- Occupancy grid
Boundary descriptor:

- HOG (on foreground edges)
- occupancy grid
Bag-of-Boundaries for smooth object retrieval

query image

Segmentation + Boundary descriptors

Set of boundary descriptors

Boundary words

sparse frequency vector

tf-idf weighting

Inverted file

querying

ranked image short-list

Geometric verification

[Arandjelovic11]

[Lowe04, Philbin07]
Bag-of-Boundaries for smooth object retrieval

Segmentation + Boundary descriptors

Set of boundary descriptors

boundary words

sparse frequency vector

tf-idf weighting

querying

ranked image short-list

Inverted file

Results

1

2

3

4

5

6

[Arandjelovic11]

[Low04, Philbin07]
Run the two complementary retrieval systems:
- Bag-of-visual-Words (BoW)
- Bag-of-Boundaries (BoB)

Soft combination, no hard decisions which system to trust

\[
\text{score(image)} = \max( \text{BoW\_score(image)}, \text{BoB\_score(image)} )
\]
Labelling

Sculptor: Giambologna
Sculpture: Hercules and the Centaur Eurytion
Labelling

- Given the matching set
  1. Identify the sculptor
  2. Name the sculpture

Query

Visual query

Matching set with meta data

Sculptor: Henry Moore
Sculpture: Oval with Points
Sculptor identification

- Image corpus was constructed by searching Flickr using sculptor names
  - Image to sculptor name (noisy) labelling is available
- Matching set images vote for the sculptor name

Query

Matching set

Visual query

Sculptor: Henry Moore
Sculpture naming

- Difficult due to noisy and insufficient meta data

Matching set with meta data

Query

- Oval with Points, 1968-70 by Henry Moore
- Henry Moore’s “Oval with Points” sculpture
  This graceful sculpture was at the Denver Botanical Gardens
- Henry Moore sculpture at Princeton
  Princeton University campus
- Oval with Points – Henry Moore – Atlanta Botanical Gardens (1)

Method:
1. Find distinctive words (keywords) in the meta data
2. Identify the sculpture via Google based query expansion
Sculpture naming: keyword extraction

- Offline meta data processing:
  - Remove sculptor name
  - Normalize data: remove HTML tags, remove file names (e.g. DSC12345.jpg, IMG12345.jpg), perform automatic translation to English.

- Find distinctive and representative keywords from the normalized meta data of the matching set
  - Sort words based on tf-idf

Matching set with meta data

Query

Visual query

Oval with Points, 1968-70 by Henry Moore

Henry Moore’s “Oval with Points” sculpture

This graceful sculpture was at the Denver Botanical Gardens

Henry Moore sculpture at Princeton

Princeton University campus

Oval with Points – Henry Moore – Atlanta

Botanical Gardens (1)

Keywords:

- oval
- points
- princeton
- botanical
- with
- campus
- atlanta
- university

(Sculpture: Oval with points)
Keywords give a strong indication of the sculpture name, but problems exist:

- Ordering of words in the name is unknown
- Not clear where to threshold the tf-idf scores
- Not all words in a sculpture name are distinctive (The Thinker; Cupid and Psyche)

Matching set can be small (e.g. 1-3 images), noisy meta data is not enough to resolve the aforementioned issues

- Use Google for query expansion of meta data
- Issue a textual Google image search query with sculptor name and top keywords
Sculpture naming: meaningful name extraction

Query

Visual query and keyword extraction

Sculptor: Henry Moore

Keywords:
- oval
- points
- princeton
- botanical
- with
- campus
- atlanta
- university

Google image titles:
- EXPLORE: Oval with Points [Henry Moore @ Kew]
- Henry Moore exhibit at Kew Gardens << An American in London
- Henry Moore: In the garden of delights - Telegraph
- Henry Moore - Works in Public - Working Model for Oval With Points ...
- Sculpture | UJUO - Part 4
- File:Oval with Points.jpg - Wikipedia, the free encyclopedia
- Oval with Points
- Henry Moore at Kew - "Oval with points" and Palm House:: OS grid ...
- File:Oval with points, a Henry Moore sculpture at Kew Gardens ...
- Oval with Points 1968-1970 Henry Moore S (image preview: FOT410056 ...
- Henry Moore, Perry Green - Moore in America - acclaimed exhibition ...
- Henry Moore oval with points - search in pictures
- Photo: "Oval With Points" by Henry Moore | Princeton Gardens and ...
Sculpture naming: meaningful name extraction

- Find common substrings in the retrieved image titles, which contain the top keyword

**Query**

**Sculptor:** Henry Moore

**Keywords:** oval, points, princeton, botanical, with campus, atlanta, university...

**Google image titles:**
- EXPLORE: Oval with Points [Henry Moore @ Kew]
- Henry Moore exhibit at Kew Gardens << An American in London
- Henry Moore: In the garden of delights - Telegraph
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- Henry Moore oval with points - search in pictures
- Photo: "Oval With Points" by Henry Moore | Princeton Gardens and ...
Results: meaningful name extraction

Michelangelo
David

St Michael and the Devil Coventry Cathedral

Jacob Epstein

Rock Drill

Anish Kapoor
Cloud Gate

Auguste Rodin
The Thinker

Henry Moore
Large Upright Internal External Form

Claes Oldenburg
Spoonbridge and Cherry

Auguste Rodin
The Three Shades

Carl Milles
Hand of God Sculpture

Benvenuto Cellini
Perseus with the Head of Medusa

Antonio Canova
Cupid and Psyche

Henry Moore
Oval with Points
Evaluation

- 200 randomly selected queries from the dataset
- A random sample:
Results

Visual matching performance:
- Proportion of queries for which the query sculpture appears in the top four retrieved results
  - BoB: 60.5%
  - BoW: 63.5%
  - Combined BoB and BoW: 83.5%

Number of positives before the first negative: BoB / BoW

<table>
<thead>
<tr>
<th>BoB</th>
<th>BoW</th>
</tr>
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<tbody>
<tr>
<td>12/0</td>
<td>6/0</td>
</tr>
<tr>
<td>4/0</td>
<td>1/0</td>
</tr>
<tr>
<td>1/0</td>
<td>3/0</td>
</tr>
</tbody>
</table>

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1/7</td>
<td>1/3</td>
<td>0/10</td>
<td>0/2</td>
<td>1/7</td>
<td>0/1</td>
<td></td>
</tr>
</tbody>
</table>
Results

- **Visual matching performance:**
  - Combined BoB and BoW: **83.5%**

- **Sculptor identification:**
  - Combined BoB and BoW: **78.5%**

- **Sculpture naming:**
  - Combined BoB and BoW: **61.5%**
Results

- **Visual matching performance:**
  - Combined BoB and BoW: 83.5%

- **Sculptor identification:**
  - Combined BoB and BoW: 78.5%

- **Sculpture naming:**
  - Combined BoB and BoW: 61.5%

- Good identification performance given there are many difficulties even if visual matching is successful:
  - Bad or non-existent meta data
  - Textual description can be dominated by the sculpture location, e.g. names of museums or sculpture parks
  - Rare words, such as spelling errors, slang, unusual names etc, can dominate the results as they are deemed to be highly informative
We have demonstrated a fully automatic system capable of immediately naming sculptors and sculptures, from a query image of a particular sculpture.
Future work

- Increase the database size:
  - Improves the chances of visual matching success
  - More likely to have useful meta data
  - Increase sculpture coverage