Beyond 2D-Grids: A Dependence Maximization View on Image Browsing

Authors

Novi Quadrianto[1] | Kristian Kersting[2] | Tinne Tuytelaars[3] | Wray L. Buntine[1]

1: NICTA & Australian National University | 2: Fraunhofer IAIS | 3: KU Leuven

Abstract

- Many existing image search engines arrange returned results in some default order on the screen, typically the relevance to a query (keyword), only.
- Arguably, a more flexible and intuitive way would be to sort images into arbitrary structures such as grids, hierarchies, or spheres so that images that are visually or semantically alike are in proximal locations.
- Arbitrary structures pose challenges as computing cross-similarities between images and structure coordinates will be a difficult task.
- We instead exploit a recently developed machine learning technique: kernelized sorting.
- We extend the technique so that some images can be pre-selected to guide the layouting process.

Kernelized Sorting

Kernelized sorting (Quadrianto et al. 2009) is

- a general technique to perform matching between pairs of objects from different domains which only requires a similarity measure within each of the two domains.

Some advantages of using kernelized sorting for image browser are

- producing a non-overlapping layout to enchance user's ability to have a good global overview of massive amount of images;
- providing flexibility in choosing the underlying structure, can be 2D grids, spirals, spheres, or even hierarchical structures.

Algorithm

Input Two sets of objects $X = \{x_1, \ldots, x_m\}$ and $Y = \{y_1, \ldots, y_m\}$
Compute kernel similarity matrix K on set X
Compute kernel similarity matrix L on set Y
Center the kernel matrices:
$\bar{K} := HKH$ and $\bar{L} := HLH$ with $H_{ij} = \delta_{ij} - m^{-1}$
while not converge **do**
Solve linear assignment problem

$$\pi_{i+1} \leftarrow \operatorname*{argmax}_{\pi \in P_m} \left[\operatorname{tr} \bar{K} \pi^\top \bar{L} \pi_i \right]$$

$$\text{with } P_m := \left\{ \begin{array}{l} \pi \in \mathbb{R}^{m \times m} \text{ where } \pi_{ij} \geq 0 \text{ and} \\ \sum_i \pi_{ij} = 1 \text{ and } \sum_j \pi_{ij} = 1 \end{array} \right\}$$

end while
Return Locally optimum permutation matrix π^*

Kernelized Sorting with Preference Constraint

Motivation

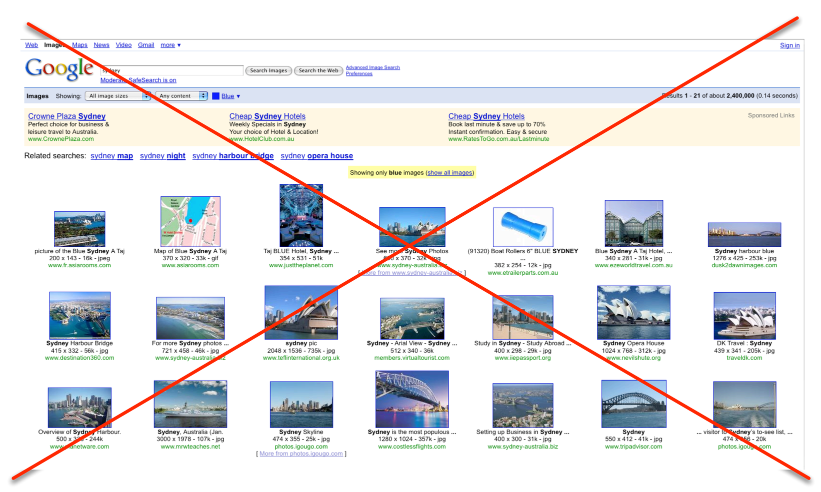
- Kernelized sorting technique does not accommodate injection of information or preferences to steer the layout of the images.
- We want to allow the user to express a small amount of preferences, for example blue images are placed at "north pole" of the sphere whereas black images are placed at the "south pole".

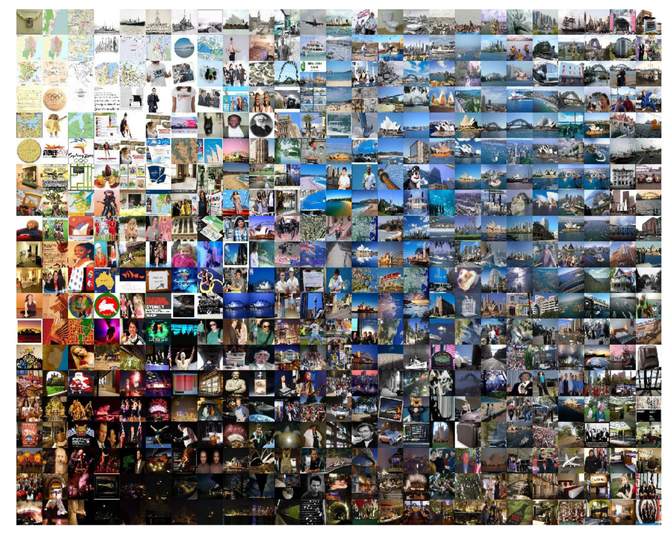
Solution

- We modify the constraint sets (while retaining the objective function un-touched) of the original kernelized sorting to express preferences.
- After some manipulations, we end up at the problem amenable to the same optimization technique as the original kernelized sorting.

Applications

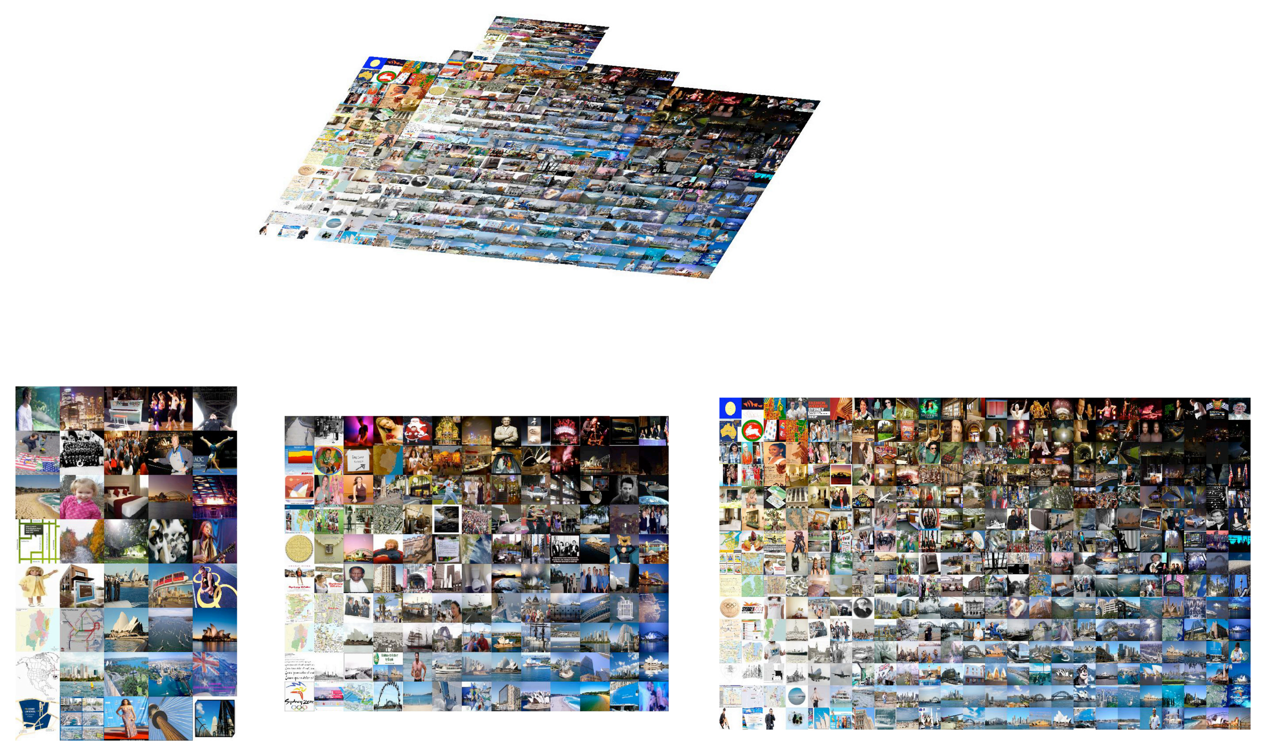
Bridging Keyword-based and Semantic-based Search





Hierarchical Search System

Hierarchy of Grids



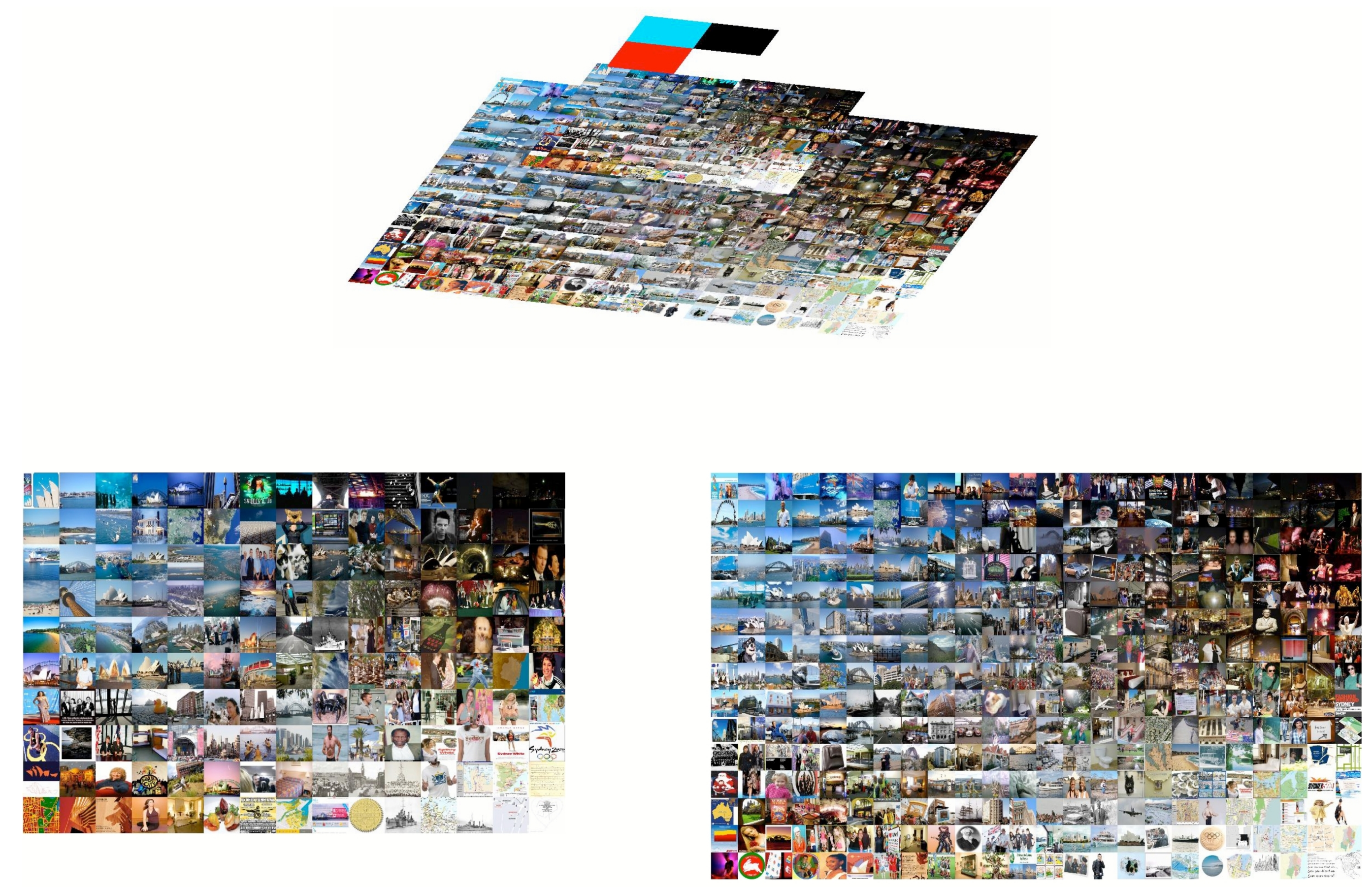
Top Level | Middle Level | Bottom Level

Hierarchy of Spheres

Top Level | Middle Level | Bottom Level

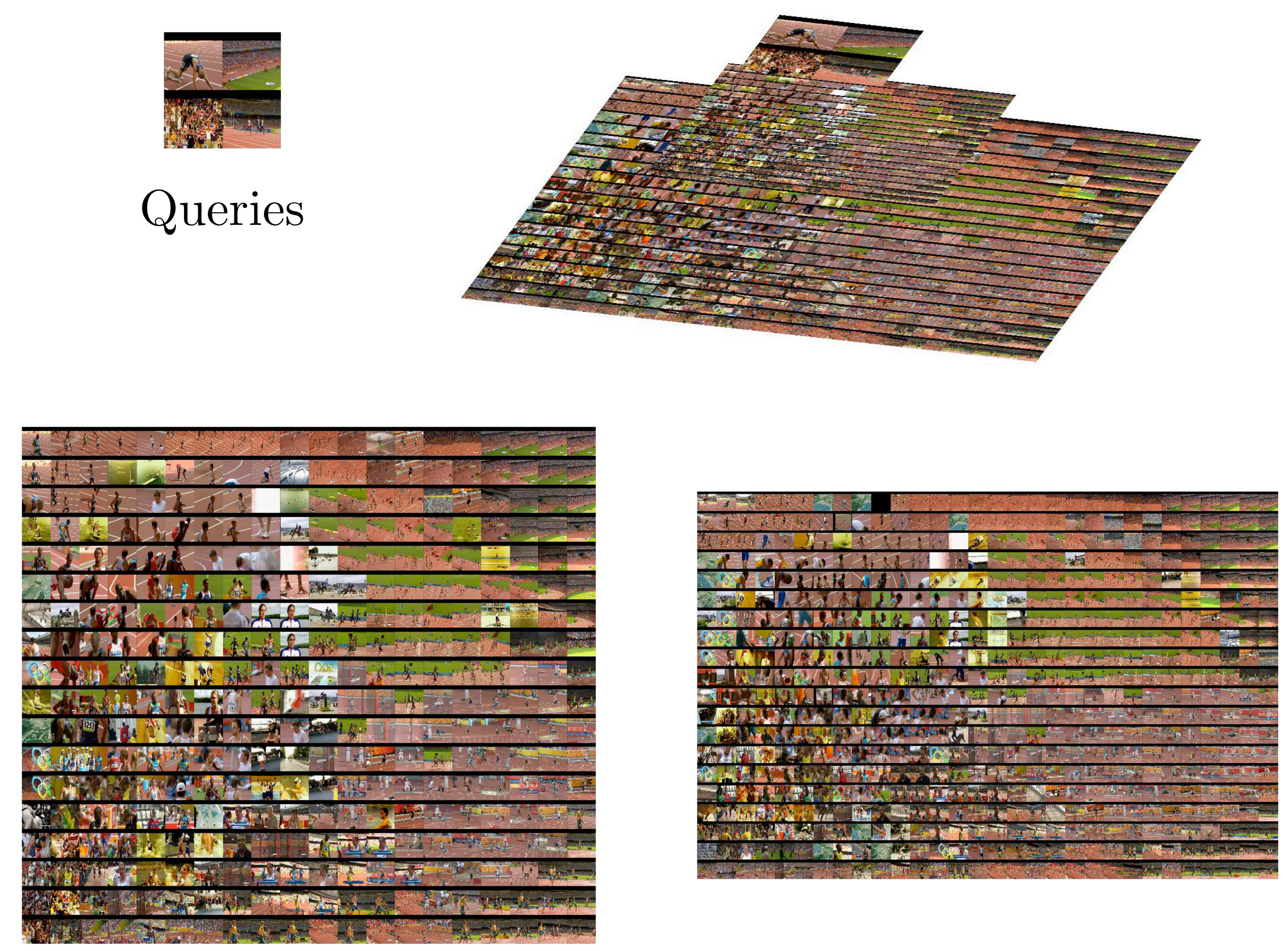
Hierarchical Search System with Preferences

Color Preference (with Lab color space features)



Middle Level | Bottom Level

Semantic Preference (with SIFT features (Lowe 2004))



Middle Level | Bottom Level

References

- N. Quadrianto, A. J. Smola, L. Song, and T. Tuytelaars. Kernelized sorting. *IEEE Trans. on Pattern Analysis and Machine Intelligence*, (in press), 2009.
- D. G. Lowe. Distinctive image features from scale-invariant keypoints. *IJCV*, 60:91–110, 2004.