Unsupervised Distance Learning by Rank Correlation Measures for Image Retrieval

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1. Introduction

Recently, unsupervised post-processing approaches have been attracted a lot of attention in image retrieval tasks, achieving significant improvements in the effectiveness of image search systems.

For global distance analysis, the ranked lists represents a rich source of information, estabilshing relationships not only between pair of images (as distance measures), but among all images in a collection. In this scenario, we exploit rank correlation measures for unsupervised distance learning tasks.

In summary, the contributions of this work are threefold:

- The RL-Sim* Algorithm, which uses information from both rank correlation measures and top-k lists overlap;
- The evaluation of six different rank correlation measures for the proposed algorithm;
- The proposal of two novel rank correlation measures for unsupervised distance learning.

2. RL-Sim* Algorithm

The RL-Sim Algorithm is a recently proposed unsupervised distance learning method that improves the effectiveness of image retrieval tasks though an iterative re-ranking scheme based on rank correlation measures between top-k positions.

However, where there is no overlap between top-k positions, the rank correlation measures have no enough information for improving the distance measure.

Therefore, the RL-Sim* condisers segmented the ranked lists for computing the new distance measures.

3. Rank Correlation Measures

The RL-Sim and RL-Sim* presents a generic modelling, allowing the use of different rank correlation measure. In this work, six classical and recent correlation measures were evaluated:

- **Intersection Measure:** based on the overlap between top-k lists at different depths;
- **Kendall τ:** a traditional rank correlation measure, based on the number of concordant pairs in the rankings;
- **Spearman:** can be seen as the L1 distance between two permutations;
- **Godman:** based on the number of concordant and non-concordant pairs;
- **Jaccard:** distance the Jaccard coefficient is a well-known distance between sets;
- **Rank Biased Overlap (RBO):** a recently proposed rank correlation measure that compares the overlap of the two rankings at incrementally increasing depths.

Two novel correlation measures were proposed: **Kendall τ_w** and **Jaccard$_l$**. Both the original Kendall and Jaccard measures does not assign higher weights to top positions of ranked lists. The novel proposed measures address this drawback.

4. Experimental Evaluation

Extensive experiments were conducted considering four different public image collections:

- *Soccer* (280 images, 3 descriptors); *MPEG-7* (1,400 images, 6 descriptors); *Brodatz* (1,176 images, 3 descriptors); *N-S Dataset* (10,200 images, 5 descriptors).

•RL-Sim* Algorithm – Effectiveness Evaluation:

N-S Dataset, considering the N-S score (interval [1,4]):

Descriptor	Initial Score	Intersection	Kendallτ	Spearman	Goodman	Jaccard	RBO	Jaccard$_l$	Kendallτ_w
ACC	3.36	3.54	3.51	3.45	1.06	3.47	3.54	**3.55**	3.52
BIC	3.04	3.20	3.17	3.02	1.05	3.13	3.19	**3.21**	3.19
CEED	2.61	2.75	2.71	2.56	1.04	2.68	2.75	**2.76**	2.74
FCTH	2.73	2.84	2.79	2.63	1.04	2.77	2.84	**2.85**	2.81
JCD	2.79	2.92	2.88	2.72	2.87	2.85	2.92	**2.93**	2.9
SIFT	2.54	2.81	2.82	**2.86**	1.03	2.77	2.79	2.80	2.80
Average	2.84	3.01	2.98	2.87	1.35	2.94	3.01	**3.02**	2.99

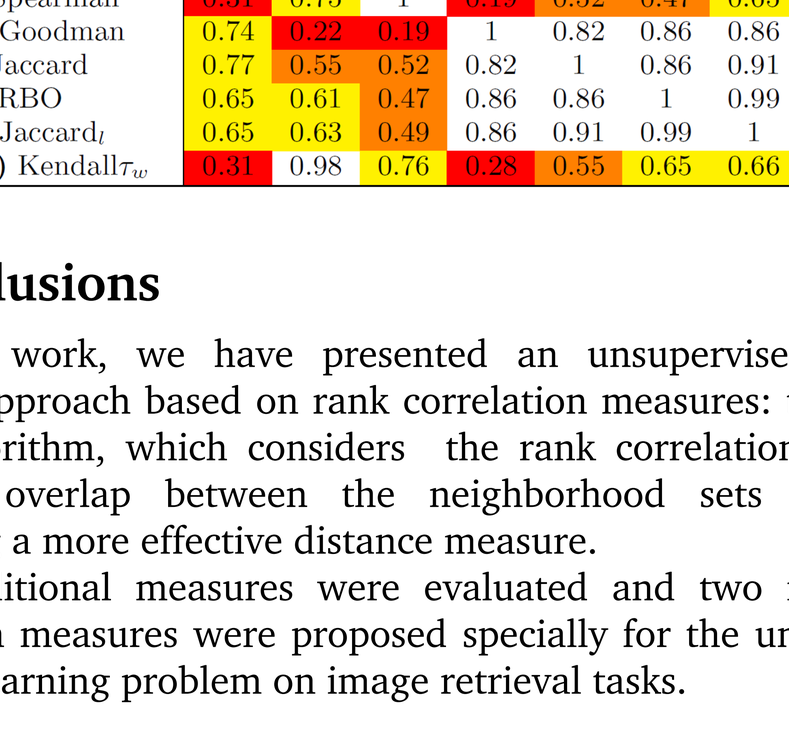
MPEG-7, Soccer and Brodatz, considering MAP as score:

Descriptor	Type	Initial MAP	Intersection	Kendallτ	Spearman	Goodman	Jaccard	RBO	Jaccard$_l$	Kendallτ_w
SS	Shape	37.67	44.10	46.54	44.70	44.11	45.49	44.23	46.60	**47.87**
BAS	Shape	71.52	76.05	76.12	75.94	72.61	74.87	77.34	77.51	**77.75**
IDSC	Shape	81.70	87.38	87.59	85.03	83.50	87.03	**88.26**	88.08	88.02
CFD	Shape	80.71	90.15	90.07	86.57	86.19	89.51	**91.13**	90.91	90.81
ASC	Shape	85.28	89.96	90.14	88.03	85.75	89.54	90.57	90.77	**90.84**
AIR	Shape	89.39	96.17	95.94	**97.86**	96.08	97.72	96.08	96.78	97.23
GCH	Color	32.24	33.99	33.93	34.29	33.38	33.43	33.99	34.04	**34.39**
ACC	Color	37.23	45.19	**45.94**	44.91	42.77	45.63	44.03	44.60	45.75
BIC	Color	39.26	45.42	45.10	45.40	43.05	44.56	45.10	45.47	**45.50**
LBP	Texture	48.40	48.83	48.94	47.32	49.06	46.53	**51.00**	50.10	49.92
CCOM	Texture	57.57	62.89	62.44	59.02	61.19	61.37	**64.23**	64.06	63.53
LAS	Texture	75.15	78.58	78.49	75.74	75.76	76.76	**79.80**	79.57	79.34
Average	-	61.34	66.56	66.77	65.4	59.93	66.04	67.15	67.37	**67.59**

- Summary of Best MAP scores for MPEG-7, Soccer and Brodatz datasets:

Descriptor	Initial MAP	Rank Measure	RL-Sim* MAP	Relative Gain (%)
SS	37.67	Kendall τ_w	47.87	+27.08
BAS	71.52	Kendall τ_w	77.75	+8.71
IDSC	81.70	RBO	88.26	+8.03
CFD	80.71	RBO	91.13	+12.91
ASC	85.28	Kendall τ_w	90.84	+6.52
AIR	89.39	Spearman	97.86	+9.48
GCH	32.24	Kendall τ_w	34.39	+6.67
ACC	37.23	Kendall τ	45.94	+23.40
BIC	39.26	Kendall τ_w	45.50	+15.89
LBP	48.40	RBO	51.00	+5.37
CCOM	57.57	RBO	64.23	+11.57
LAS	75.15	RBO	79.80	+6.19

•Impact of parameter k for different measures (MPEG-7 dataset):



•Correlation among Rank Correlation Measures:

Rank Measures	(I)	(K)	(S)	(G)	(J)	(R)	(J$_l$)	(K$_w$)
(I) Intersection	1	0.23	0.31	0.74	0.77	0.65	0.65	0.31
(K) Kendallτ	0.23	1	0.75	0.22	0.55	0.61	0.63	0.98
(S) Spearman	0.31	0.75	1	0.19	0.52	0.47	0.65	0.76
(G) Goodman	0.74	0.22	0.19	1	0.82	0.86	0.86	0.28
(J) Jaccard	0.77	0.55	0.52	0.82	1	0.86	0.91	0.55
(R) RBO	0.65	0.61	0.47	0.86	0.86	1	0.99	0.65
(J$_l$) Jaccard$_l$	0.65	0.63	0.49	0.86	0.91	0.99	1	0.66
(K$_w$) Kendallτ_w	0.31	0.98	0.76	0.28	0.55	0.65	0.66	1

5. Conclusions

In this work, we have presented an unsupervised distance learning approach based on rank correlation measures: the the RL-Sim* Algorithm, which considers the rank correlation measures and the overlap between the neighborhood sets aiming at computing a more effective distance measure.

Six traditional measures were evaluated and two novel rank correlation measures were proposed specially for the unsupervised distance learning problem on image retrieval tasks.

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