

# Experimenting with the Quantum Probability Ranking Principle

Renaissance meeting

Guido Zuccon, Leif Azzopardi, Keith van Rijsbergen

University of Glasgow  
guido@dcs.gla.ac.uk



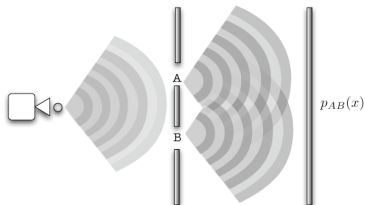
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## Document ranking:

- the relevance of a document may depend on already seen documents (e.g. subtopic retrieval)
- document dependance is ignored by traditional ranking strategies (PRP)
- ignoring document dependance may lead to sub-optimal rankings

Double slits experiment:

- Kolmogorovian probability fails to adequately describe the outcome of physical phenomena
- quantum probability theory accounts for interference between events



- Kolmogorovian law of total probability:  $\mathbf{p}_{AB}(\mathbf{x}) = \mathbf{p}_A(\mathbf{x}) + \mathbf{p}_B(\mathbf{x})$
- Quantum law of total probability:  

$$\mathbf{p}_{AB}(\mathbf{x}) = \mathbf{p}_A(\mathbf{x}) + \mathbf{p}_B(\mathbf{x}) + \mathbf{I}_{AB}(\mathbf{x})$$

from quantum law of total probability & analogy with double slit experiment we derive the QPRP:

- interference has to be accounted for
- choice of document to rank next, amongst all candidates, not only depends upon  $p_B(x)$  but also on interference,  $I_{AB}(x)$
- rank following  $d = \arg \max (P(d_i) + \sum_{d_x \in RA} I_{d_x, d_i})$

- QPRP has been tested in TREC 6, 7, 8 interactive track (novelty&diversity), for the topics with associated subtopics relevance judgements.
- QPRP has been employed to re-rank an initial result list provided by Okapi BM25.
- baseline: BM25; we also compared to state of the art IDR method, the Portfolio Theory approach (Wang, ECIR/SIGIR 2009) and MMR.
- results evaluated in terms of S-r, S-p and S-MRR.
- dimensions of the experiments: retrieval cut-off (100, 200, 1000), query length (short, long).

$$S - r(@rank) = \frac{\#subtopic-covered}{\#total-subtopics}$$

$$S - p(@recall) = \frac{Optimal-minRank-per-recall}{minRank-for-recall}$$

$$S - MRR = \frac{1}{rank-complete-coverage}$$

## QPRP:

- $p_B + \sum_{A_i \in \mathcal{A}} I_{A_i B}$
- $I_{AB} \approx -\sqrt{p_A} \sqrt{p_B} \rho_{AB}$
- $\rho_{AB}$ : Pearson's correlation of term vectors (using BM25 weights) of docs  $A$  and  $B$

## Portfolio:

- $p_B - b w_B \sigma^2 - 2b \sum_{i=1}^{k-1} w_i \sigma^2 \rho_{i,B}$
- $b$  (risk) and  $\sigma^2$  (variance) constants (but require tuning)
- $w_i = \frac{1}{\log i}$

Measure	PRP	Portfolio	QPRP
<b>S-p@0.1</b>	0.3968	0.4374 (+9.27%)	0.4237 (+6.33%)
<b>S-p@0.2</b>	0.3062	0.3001 (-2.04%)	0.3452 (+11.29%)
<b>S-p@0.3</b>	0.2445	0.2560 (+4.47%)	0.2800 (+12.67%)
<b>S-p@0.4</b>	0.2149	0.2128 (-0.97%)	0.2379 (+9.68%)
<b>S-p@0.5</b>	0.1920	0.181 (-6.07%)	0.2338 (+17.90%)
<b>S-p@0.6</b>	0.1902	0.1745 (-8.98%)	0.2082 (+8.65%)
<b>S-p@0.7</b>	0.1483	0.1459 (-1.57%)	0.1793 (+17.31%)
<b>S-p@0.8</b>	0.0749	0.0925 (+19.01%)	0.0774 (+3.25%)
<b>S-p@0.9</b>	0.0370	0.0563 (+34.16%)	0.0467 (+20.71%)
<b>S-p@1.0</b>	0.0101	0.0084 (-19.36%)	0.0116 (+13.43%)

Table: S-precision

Measure	PRP	Portfolio	QPRP
S-r@5	0.2466	0.2760 (+ 10.63%)	0.3093 (+ 20.25%)
S-r@10	0.3900	0.3553 (-9.78%)	0.4063 (+ 3.99%)
S-r@15	0.4590	0.4152 (-10.55%)	0.4629 (+ 0.82%)
S-r@20	0.4962	0.4601 (-7.85%)	0.5026 (+ 1.27%)
S-r@30	0.5478	0.5279 (-3.76%)	0.5530 (+ 0.93%)
S-r@50	0.6034	0.5939 (-1.58%)	0.6150 (+ 1.89%)
S-r@70	0.6425	0.6273 (-2.42%)	0.6433 (+ 0.12%)
S-r@80	0.6552	0.6499 (-0.81%)	0.6607 (+ 0.12%)
S-r@90	0.6716	0.6742 (+ 0.37%)	0.6738 (+ 0.32%)
S-r@100	0.6829	0.6829 -	0.6829 -

Table: S-recall

Models	S-MRR
<b>PRP</b>	0.0071
<b>Portfolio</b>	0.0145 (+50.43%)
<b>QPRP</b>	0.0162 (+55.61%)

Table: S-MRR

- QPRP improves upon PRP for all levels of S-r and S-p
- QPRP outperforms MMR and PT across most levels
- QPRP consistently outperforms other strategies across all topics in s-MRR: on each topic the QPRP returns complete coverage of all subtopics at a rank lower than all the other strategies
- QPRP, unlike MRR and PT, requires no parameter tuning!

- aim: test the QPRP in ad-hoc retrieval scenario
- compare QPRP against PT and pseudo relevance feedback mechanisms
- add more dimensions to the empirical investigation: ranking cut-off (100, 200, 500, 1000), query length (short, long), probability estimation (BM25, LM)

- QPRP models IDR using **interference**
- modeling **IDR improves rank quality** in novelty&diversity oriented tasks
- **QPRP exploits IDR better** than other state of the art models
  
- more effective way to **approximate interference**?
- true complex probability **amplitude distribution**?
- **robustness** of QPRP under wrong (first) choice?
- **application** QPRP & interference for adhoc/ structure/ aggregated/ presentation?