Black Boxes are Harmful

Rup; NIST

http://kak.tx0.org/IR

IR Experiment

- Test-collection
- Search system
- index — retrieve — evaluate loop

Why Evaluate?

- Measure effectiveness
- Establish baseline
- Render experiment reproducible

A Failed Experiment

Point of Failure

- Test-collection
- Retrieval system

Point of Failure

Test-collection

- Broken document corpus; checksum mismatch
- Wrong document-query-qrel triplet

Point of Failure

Configuration Pitfalls

- A counterintuitive interface
- One parameter, many meanings
- Switches are not mutually exclusive

Point of Failure

Word-of-mouth-heuristics

QUERY/MODEL	BM25	PL2	LM-Dirichlet	TF_IDF
TITLE	0.3–0.5	4—7	750—1000	0.3–0.5
DESCRIPTION	0.6—0.8	1—2	1500—2000	0.6—0.8

Point of Failure

A Bug

BM25 (A)	$$\frac{tf}{k_1\left(1-b+b\cdot\frac{dl}{avdl}\right)+tf}\cdot\log\left(\frac{N-n+0.5}{n+0.5}\right)\cdot\frac{(k_3+1)qtf}{k_3+qtf}$$
BM25 (B)	$$\frac{(k_1+1)tf}{k_1\left(1-b+b\cdot\frac{dl}{avdl}\right)+2\cdot tf}\cdot\log\left(\frac{N-n+0.5}{n+0.5}\right)\cdot\frac{(k_3+1)qtf}{k_3+qtf}$$

Point of Failure

Naming

Generics	Terrier	Lucene
Porter	PorterStemmer	PorterStemFilter
	WeakPorterStemmer	
Snowball	EnglishSnowballStemmer	SnowballStemFilter
S-Stemmer	SStemmer	**EnglishMinimal**StemFilter
Krovets		**K**StemFilter

Point of Failure

Naming

Terrier	Lucene
Tf	DefaultSimilarity
TF_IDF	BM25Similarity
LemurTF_IDF	TFIDFSimilarity
BM25	
DFRBM25	

Point of Failure

The Parser

- Tags/parts to include/exclude
- Stop-word removal
- Stemmer
- Curate the vocabulary

Recheck everything; to what length and end?

Alternative; Lucene

- LTR; mod of Lucene 5.4.0
- Not another blackbox
- Augment documentation

A Single Point of Reference

- TFxIDF Repository
- TXT; system with ‘correct’ implementations
- TRECBOX; facility to repeat experiments
- Evaluation table

TFxIDF Repository

SMART'S TERM-WEIGHTING TRIPLE NOTATION											
$tf(f_{ik})$				$df(N,n_k)$				$g(G,D_i)$			
	b	1	Binary weight	x	**n**	1	Multiplier of 1, disregards the collections frequency	x	**n**	1	1, disregards length normalization factor
t	**n**	f_{ik}	raw term frequency	f		$\log\left(\frac{N}{n_k}\right)$	inverse collection frequency		**c**	$\sqrt{\sum_{k=1}^{t} w_{ik}^2}$	cosine normalization
	a	$0.5+0.5\cdot\frac{f_{ik}}{\max(f_{ik})}$	augmented normalized term frequency (normalized to be in [0.5, 1])		**t**	$\log\left(\frac{N+1}{n_k}\right)$	inverse collection frequency		**u**	$1-s+s\cdot\frac{u_i}{avgu}$	pivoted unique normalization
	l	$1+\log(f_{ik})$	log	p		$\log\left(\frac{N-n_k}{n_k}\right)$	probabilistic inverse collection frequency		**b**	$1-s+s\cdot\frac{b_i}{avgb}$	pivoted byte size normalization
	L	$\frac{1+\log(f_{ik})}{1+\log(avg(f_{ik}))}$	average term frequency based normalization								
	d	$1+\log(1+\log(f_{ik}))$	double logarithm								

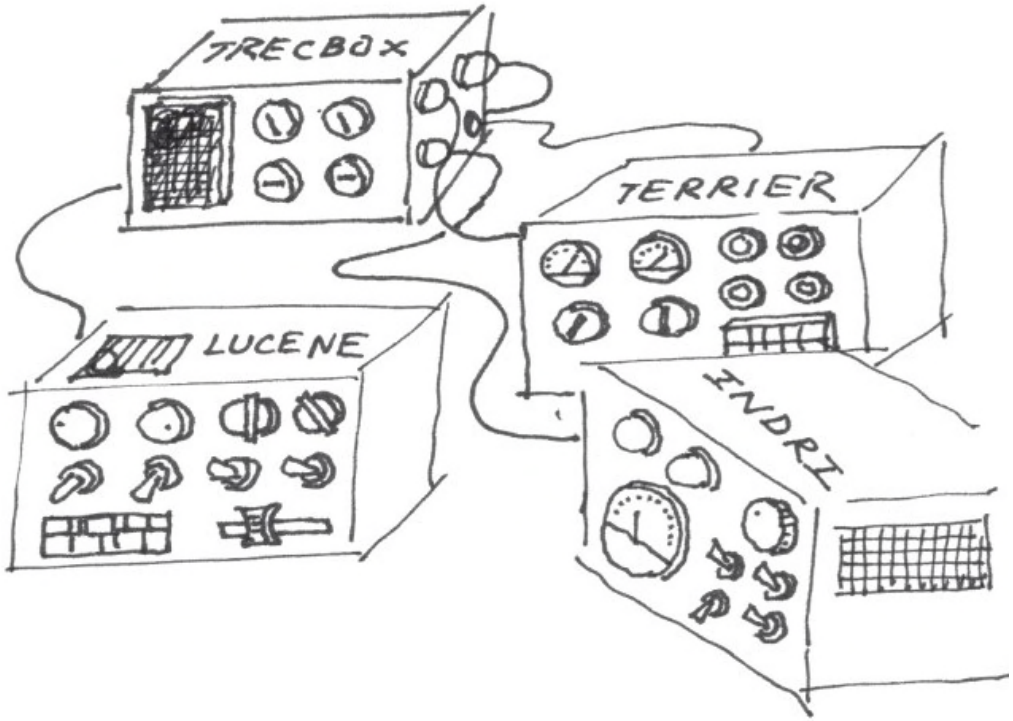
TFxIDF Repository

w	Scaling	TF	DF	QTF	Correction factor	Parameters
$BM0$		1				
$BM1$	s_3	1	$w^{(1)}$	$\frac{qtf}{k_3+qtf}$	$k_2 \cdot nq \cdot \frac{avdl-dl}{avdl+dl}$	
$BM15$	$s_1 s_3$	$\frac{tf}{k_1+tf}$	$w^{(1)}$	$\frac{qtf}{k_3+qtf}$	$k_2 \cdot nq \cdot \frac{avdl-dl}{avdl+dl}$	$s_i = \max(k_i,1)$ or 1 if $k_2 = 0$
$BM11$	$s_1 s_3$	$\frac{tf}{k_1 \cdot \frac{dl}{avdl}+tf}$	$w^{(1)}$	$\frac{qtf}{k_3+qtf}$	$k_2 \cdot nq \cdot \frac{avdl-dl}{avdl+dl}$	$s_i = \max(k_i,1)$ or 1 if $k_2 = 0$
$BM25$	$s_1 s_3$	$\frac{tf^c}{K+tf^c}$	$w^{(1)}$	$\frac{qtf}{k_3+qtf}$	$k_2 \cdot nq \cdot \frac{avdl-dl}{avdl+dl}$	$s_i = k_i+1$, $c = 1+mK$, $m \geq 0$ $K = k_1\left((1-b)+b \cdot \frac{dl}{avdl}\right)$
$BM25(k_1,k_2,k_3,b)$ The general form as a function of k_1, k_2, k_3, b and $m=0$.	$w = (k_1+1)\cdot(k_3+1)\cdot \frac{tf}{k_1\left((1-b)+b\cdot\frac{dl}{avdl}\right)+tf} \cdot \log\left(\frac{N-n+0.5}{n+0.5}\right) \cdot \frac{qtf}{k_3+qtf} + k_2 \cdot nq \cdot \frac{avdl-dl}{avdl+dl}$					
$BM25(k_1,0,k_3,b)$ The form, rearranged, after six years of trial-and-error from TREC3 to TREC8 (1995-2000)	$w = \frac{(k_1+1)\cdot tf}{k_1\left((1-b)+b\cdot\frac{dl}{avdl}\right)+tf} \cdot \log\left(\frac{N-n+0.5}{n+0.5}\right) \cdot \frac{(k_3+1)\cdot qtf}{k_3+qtf}$					

TFxIDF Repository

BMxx CONSTANTS											
	s_1	s_2	s_3	k_1	k_2	k_3	b	k_4	k_5	k_6	m
TREC 1											
TREC 2	$s_i = \max(k_i, 1)$ or 1 if $k_2 = 0$				0.0–0.3	∞					
TREC 3	$s_i = k_i + 1$			2	0	8, ∞	0.75				0
TREC 4	$s_i = k_i + 1$			1–2	0	8	0.6–0.75				0
TREC 5	$s_i = k_i + 1$			1–2	0	8, 1000	0.6–0.75				0
TREC 6	$s_i = k_i + 1$			1.2	0	0–1000	0.75	-0.7 or 0	0–4	4–∞	0
TREC 7	$s_i = k_i + 1$			1.2, 2	0	0–1000	0.75, 0.8	-0.7 or 0	0–4	4–∞	0
TREC 8	$s_i = k_i + 1$			1.2	0	7 or 1000	0.75				0

TRECBOX



TRECBOX

Settings.txt

```
EVAL /Users/rup/ir/trec_eval.9.0
LUCENE /Users/rup/ir/LTR
TERRIER /Users/rup/ir/TTR
LEMUR /Users/rup/ir/indri
EXP /Users/rup/ir/sub-collections
```

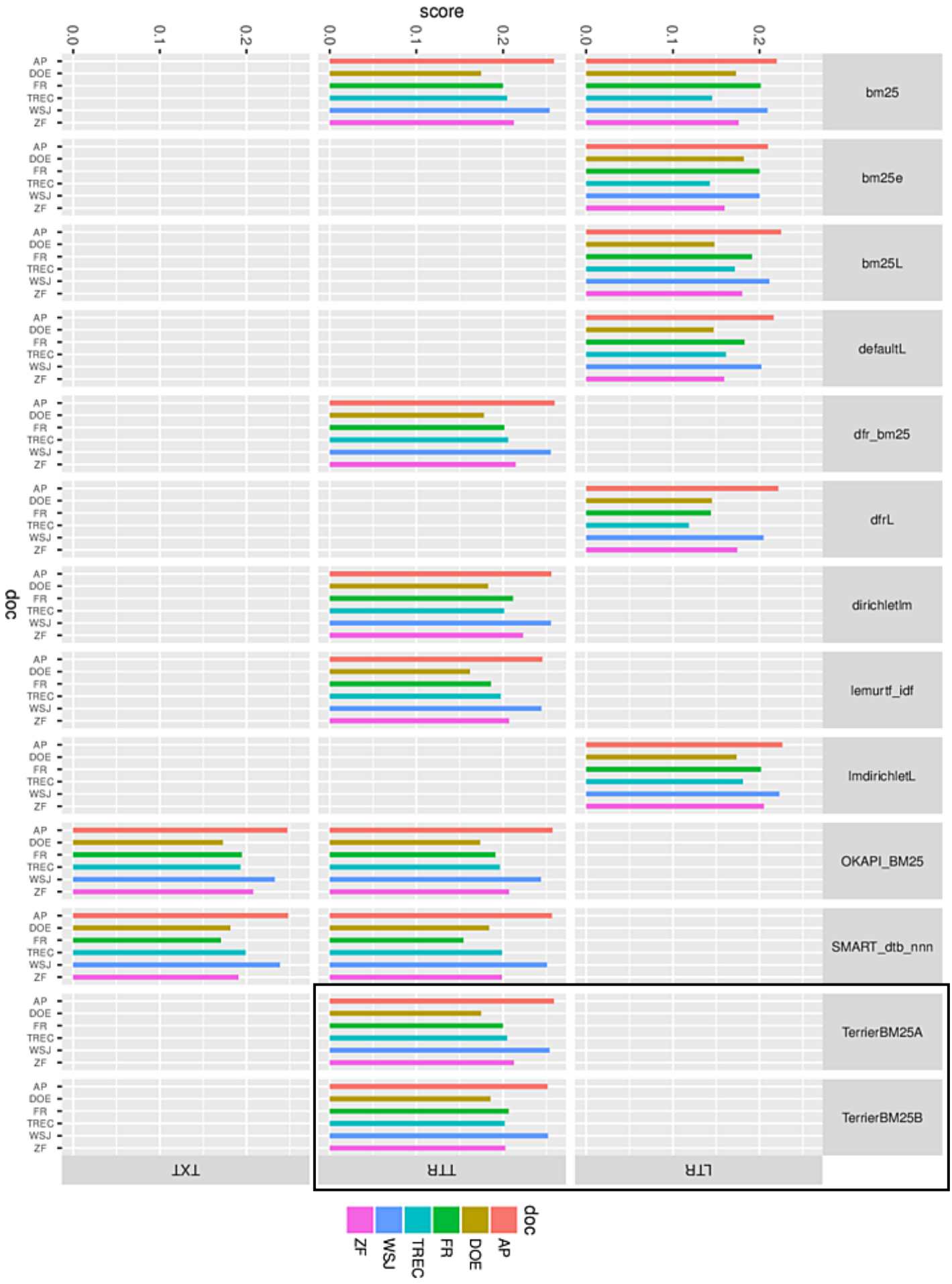
Experiment.txt

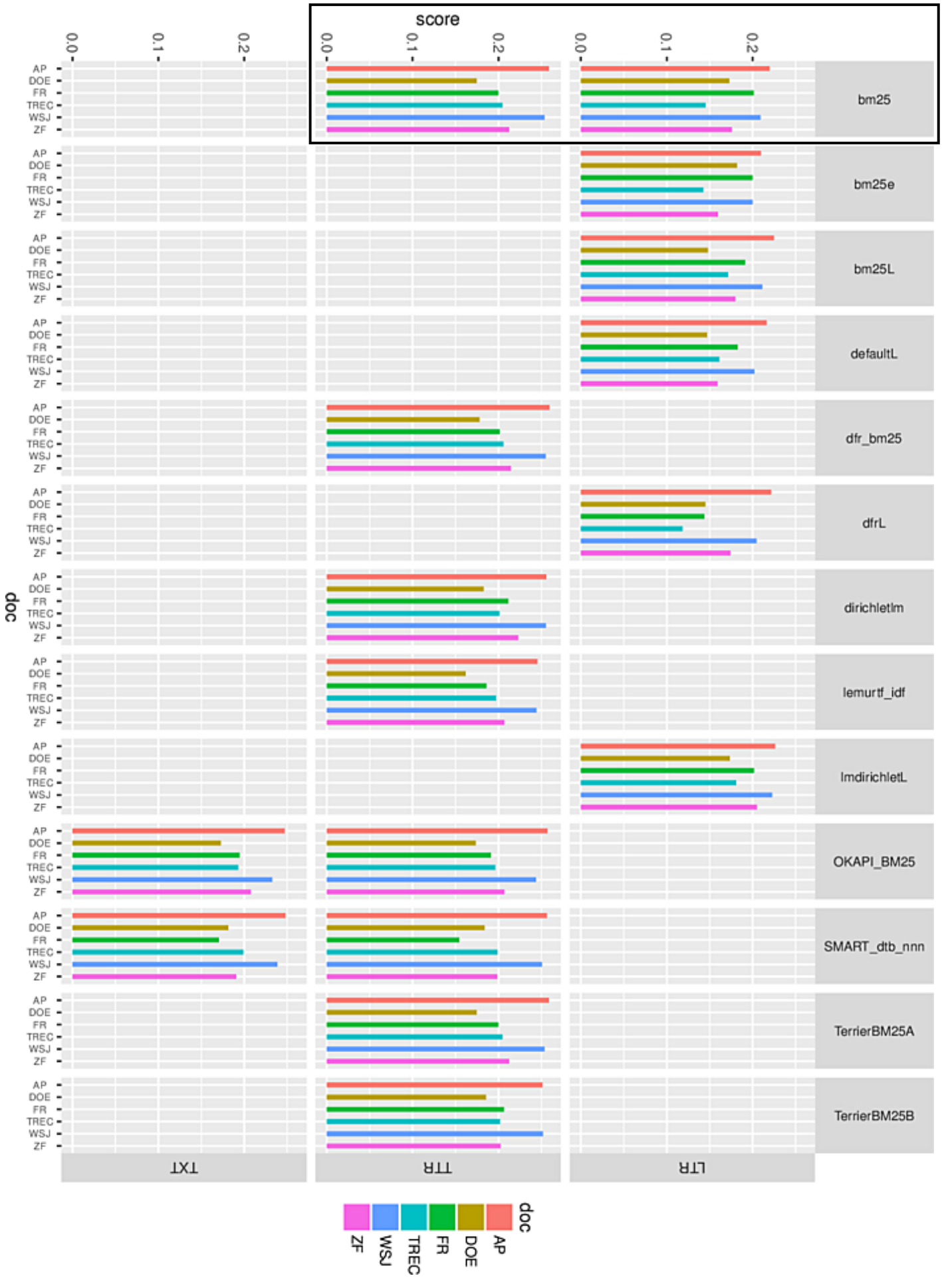
```
TESTCOL AP       AP     1-450:T:1-200.AP.196   1-200.AP.196.qrel
TESTCOL DOE      DOE    1-450:T:1-200.DOE.80   1-200.DOE.80.qrel
TESTCOL FR       FR     1-450:T:1-200.FR.111   1-200.FR.111.qrel
TESTCOL TREC     cd12   1-450:T:1-200.TREC.200 1-200.TREC.200.qrel
TESTCOL WSJ      WSJ    1-450:T:1-200.WSJ.200  1-200.WSJ.200.qrel
TESTCOL ZF       ZF     1-450:T:1-200.ZF.122   1-200.ZF.122.qrel

MODEL bm25 dirichletlm lemurtf_idf dfr_bm25
MODEL SMART_dtb_nnn OKAPI_BM25 TerrierBM25A TerrierBM25B
STEM x porter
STOP smart571
QEXP x
SYS terrier
```

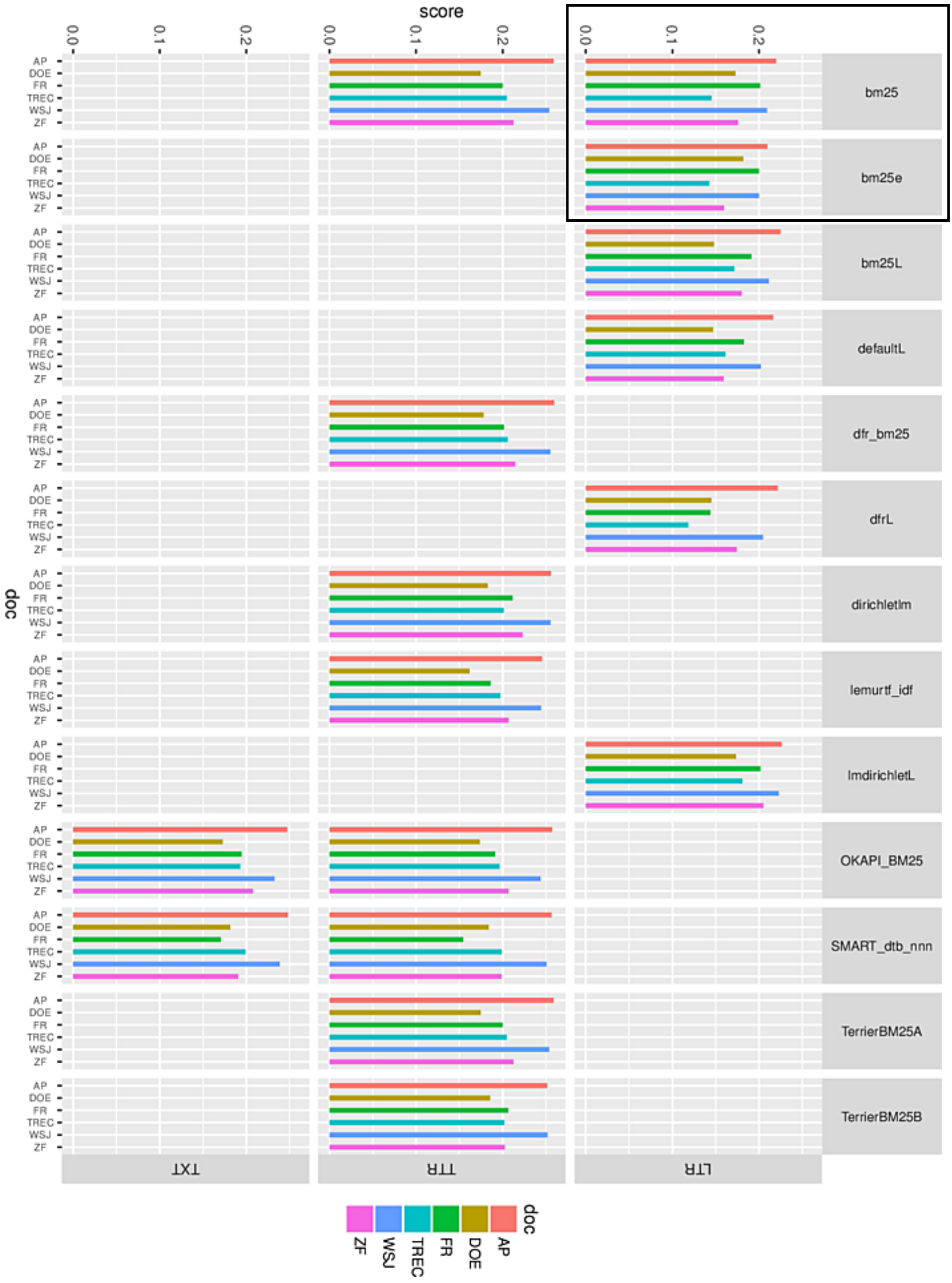
Evaluation Table

- System x Model x Doc
- Sanity-check

bm25
bm25e
bm25L
defaultL
dfr_bm25
dfrL
dirichletlm
lemurtf_idf
lmdirichletL
OKAPI_BM25
SMART_dtb_nnn
TerrierBM25A
TerrierBM25B
LTR
TTR
TXT
score
0.0
0.1
0.2
doc
AP
DOE
FR
TREC
WSJ
ZF


score
0.0
0.1
0.2
doc
AP
DOE
FR
TREC
WSJ
ZF
bm25
bm25e
bm25L
defaultL
dfr_bm25
dfrL
dirichletlm
lemurtf_idf
lmdirichletL
OKAPI_BM25
SMART_dtb_nnn
TerrierBM25A
TerrierBM25B
TXT
TTR
LTR


score
0.0
0.1
0.2
doc
AP
DOE
FR
TREC
WSJ
ZF
bm25
bm25e
bm25L
defaultL
dfr_bm25
dfrL
dirichletlm
lemurtf_idf
lmdirichletL
OKAPI_BM25
SMART_dtb_nnn
TerrierBM25A
TerrierBM25B
TXT
TTR
LTR


score
0.0
0.1
0.2
doc
AP
DOE
FR
TREC
WSJ
ZF
bm25
bm25e
bm25L
defaultL
dfr_bm25
dfrL
dirichletlm
lemurtf_idf
lmdirichletL
OKAPI_BM25
SMART_dtb_nnn
TerrierBM25A
TerrierBM25B
TXT
TTR
LTR

bm25
bm25e
bm25L
defaultL
dfr_bm25
dfrL
dirichletlm
lemurtf_idf
lmdirichletL
OKAPI_BM25
SMART_dtb_nnn
TerrierBM25A
TerrierBM25B
LTR
TTR
TXT
score
0.0
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0.2
doc
AP
DOE
FR
TREC
WSJ
ZF

Lucene's Similarity-Score Computation

‘Conceptual’ formula

$$score(q,d) = coord\text{-}factor(q,d) * query\text{-}boost(q) * \frac{V(q) * V(d)}{|V(q)|} * doc\text{-}len\text{-}norm(d) * doc\text{-}boost(d)$$

‘Practical’ scoring formula

$$score(q,d) = coord(q,d) * queryNorm(q) * \sum_{t \text{ in } q} (tf(t \text{ in } d) * idf(t)^2 * t.getBoost() * norm(t,d))$$

Generalized

$$score(Q,D) = f_c(Q,D) \cdot f_q(Q) \cdot \sum_{T_k \in Q \cap D} \left(tf(T_k) \cdot df(T_k) \cdot f_b(T_k) \cdot f_n(T_k, D) \right)$$

	w_i	w_j
BM25(k1,0,k3,b)	$\frac{(k_1+1)f_{ik}}{k_1\left((1-b)+b\cdot\frac{dl_i}{avdl}\right)+f_{ik}}\cdot\log\left(\frac{N-n_k+0.5}{n_k+0.5}\right)$	$\frac{(k_3+1)f_{jk}}{k_3+f_{jk}}$
	T * I	Q
dtb.nnn	$\frac{1+\log\left(1+\log\left(f_{ik}\right)\right)\cdot\log\left(\frac{N+1}{n_k}\right)}{1-s+s\cdot\frac{b_i}{avgb}}$	f_{jk}
	T * I / L	Q

$$score(D_i, D_j) = \sum_{T_k \in D_i \cap D_j} w_i \cdot w_j$$

$score(Q,D)$	=	$f_c(Q,D)$	•	$f_q(Q)$	•	$\sum_{T_k \in Q \cap D}$	(	$tf(T_k)$	•	$df(T_k)$	•	$f_b(T_k)$	•	$f_n(T_k,D)$	)
BM25(k1,0,k3,b)	=	1	•	1	•	$\sum_{T_k \in Q \cap D}$	(	T	•	I	•	Q	•	1	)
dtb.nnn	=	1	•	1	•	$\sum_{T_k \in Q \cap D}$	(	T	•	I	•	Q	•	L	)

	Description	**Function names in code**
	Coordination factor	coord()
	Query normalization factor	queryNorm()
	Term-frequency transformation	tf()
	Document-frequency transformation	idf()
	Query boost	in computeWeight()
	Document length normalization	lengthNorm()

In Conclusion

- Test-collection statistics
- Design documentation
- Consistent naming, well-defined notation
- Evaluation table
- Sharable experimental artifacts
- Implementations traceable to a source

Thank you.

Resources

- Experimental Methods for Information Retrieval (Donald Metzler and Oren Kurland, SIGIR 2012)

http://iew3.technion.ac.il/~kurland/sigir12-tutorial.pdf

- TFxIDF Repository (and other notes/tools)

http://kak.tx0.org/IR/TFxIDF