Using Unigram and Bigram Language Models for Monolingual and Cross-Language IR

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3. Using Different Indexing Units
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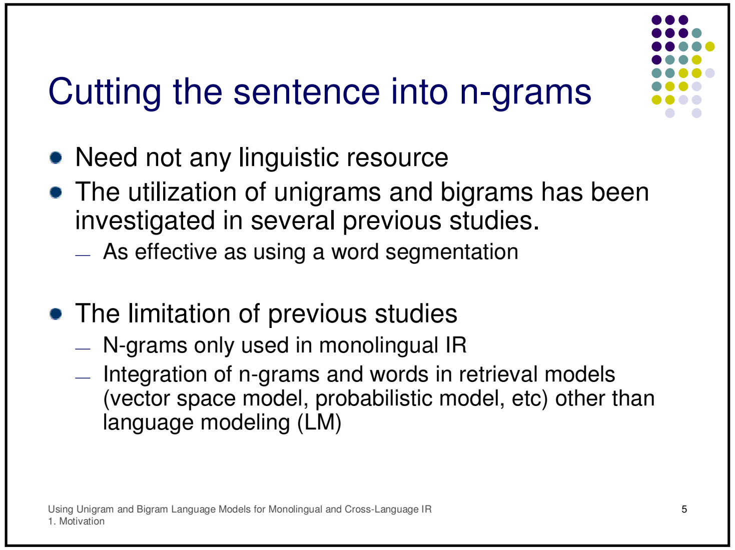
The difference between East-Asian and most European languages

- A common problem in East-Asian languages (Chinese, Japanese and Korean to some extent) is the lack of natural word boundaries.
- For information retrieval, we have to determine the index units first.
  - Using word segmentation
  - Cutting sentence into n-grams

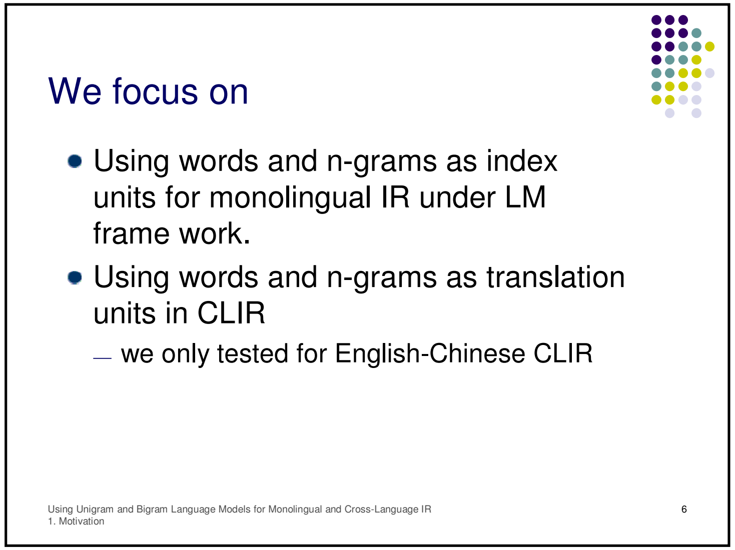
Word segmentation

- Based on rules, dictionaries and/or statistics
- Problems for information retrieval
  - Segmentation Ambiguity: The same string can be segmented into different words
    e.g. "发展中国家" ➔
    发展中(developing)/国家(country)
    发展(development)/中(middle)/国家(country)
    发展(development)/中国(China)/家(family)
  - If a document and a query are segmented into different words, there may be mismatch.
  - Two different words may have the same or related meaning, especially when they share come common characters.
    办公室(office) ↔ 办公楼(office building)



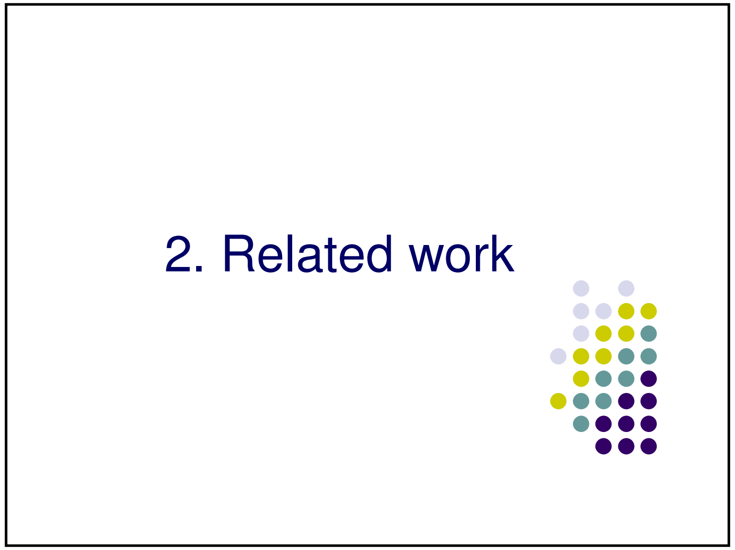
Cutting the sentence into n-grams

- Need not any linguistic resource
- The utilization of unigrams and bigrams has been investigated in several previous studies.
  - As effective as using a word segmentation
- The limitation of previous studies
  - N-grams only used in monolingual IR
  - Integration of n-grams and words in retrieval models (vector space model, probabilistic model, etc) other than language modeling (LM)

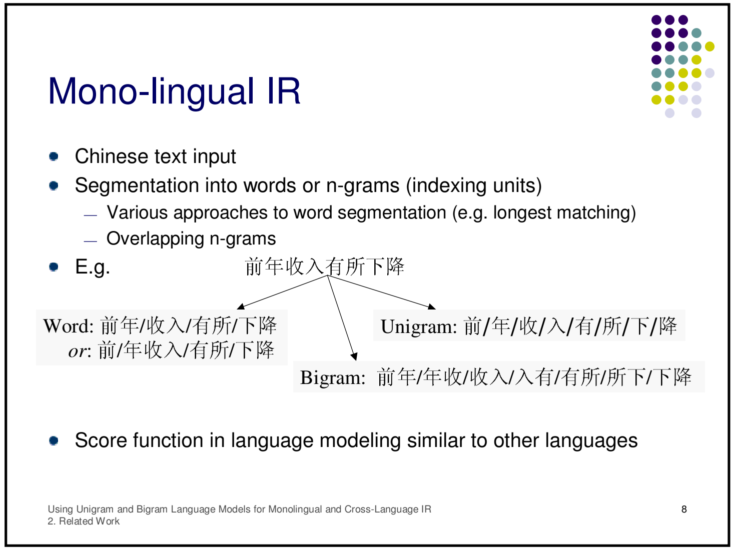


We focus on

- Using words and n-grams as index units for monolingual IR under LM frame work.
- Using words and n-grams as translation units in CLIR
  - we only tested for English-Chinese CLIR



2. Related work



Mono-lingual IR

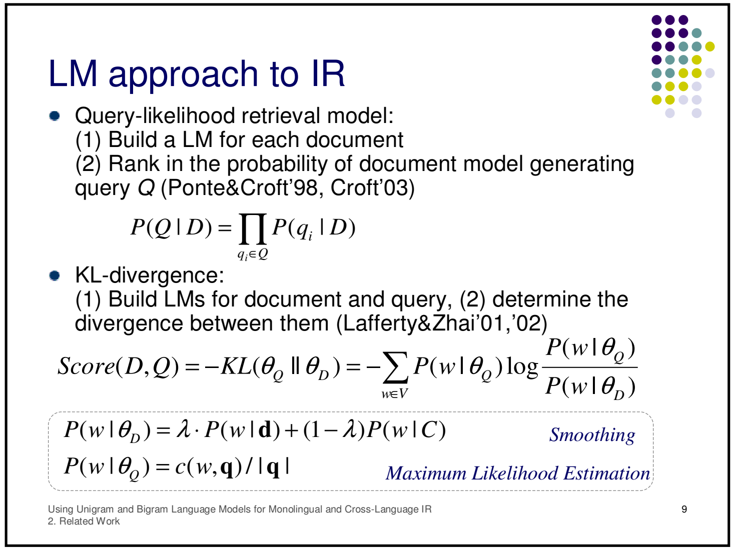
- Chinese text input
- Segmentation into words or n-grams (indexing units)
  - Various approaches to word segmentation (e.g. longest matching)
  - Overlapping n-grams
- E.g. 前年收入有所下降

Word: 前年/收入/有所/下降
or: 前/年收入/有所/下降

Unigram: 前/年/收/入/有/所/下/降

Bigram: 前年/年收/收入/入有/有所/所下/下降

- Score function in language modeling similar to other languages



LM approach to IR

- Query-likelihood retrieval model:
  (1) Build a LM for each document
  (2) Rank in the probability of document model generating query *Q* (Ponte&Croft'98, Croft'03)

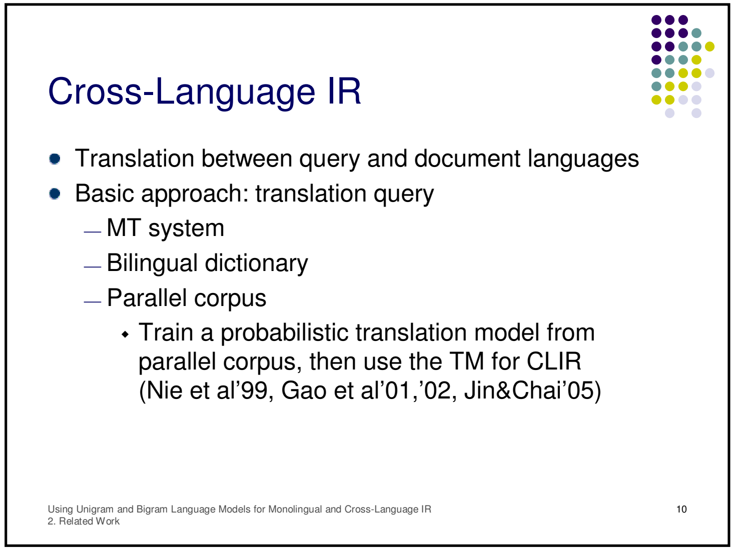
$$P(Q \mid D) = \prod_{q_i \in Q} P(q_i \mid D)$$

- KL-divergence:
  (1) Build LMs for document and query, (2) determine the divergence between them (Lafferty&Zhai'01,'02)

$$Score(D,Q) = -KL(\theta_Q \parallel \theta_D) = -\sum_{w \in V} P(w \mid \theta_Q) \log \frac{P(w \mid \theta_Q)}{P(w \mid \theta_D)}$$

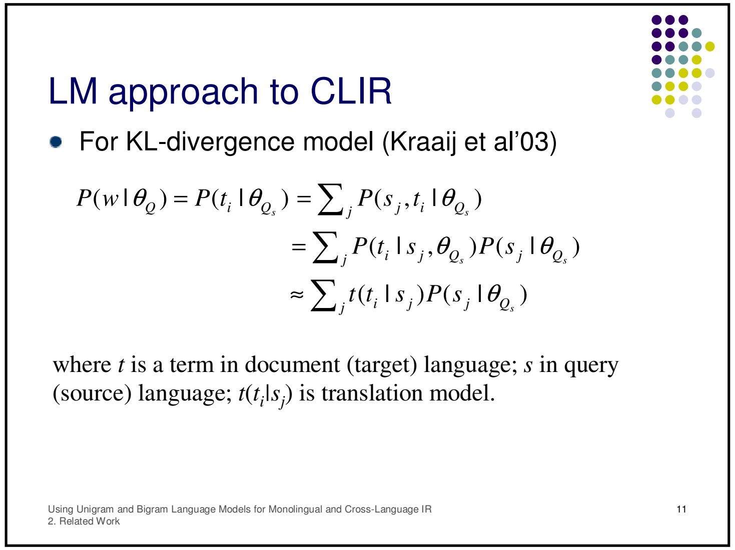
$$P(w \mid \theta_D) = \lambda \cdot P(w \mid \mathbf{d}) + (1-\lambda) P(w \mid C) \quad \textit{Smoothing}$$

$$P(w \mid \theta_Q) = c(w, \mathbf{q}) / |\mathbf{q}| \quad \textit{Maximum Likelihood Estimation}$$



Cross-Language IR

- Translation between query and document languages
- Basic approach: translation query
  - — MT system
  - — Bilingual dictionary
  - — Parallel corpus
    - Train a probabilistic translation model from parallel corpus, then use the TM for CLIR (Nie et al'99, Gao et al'01,'02, Jin&Chai'05)

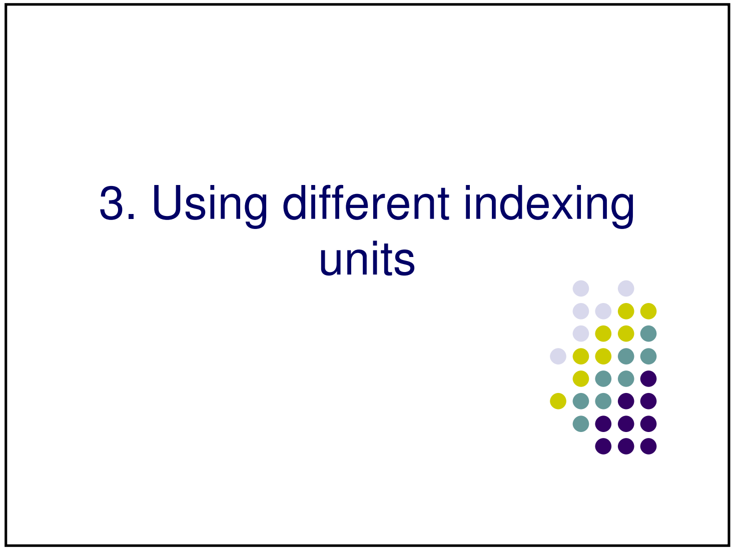


LM approach to CLIR

- For KL-divergence model (Kraaij et al'03)

$$\begin{aligned} P(w \mid \theta_Q) = P(t_i \mid \theta_{Q_s}) &= \textstyle\sum_j P(s_j, t_i \mid \theta_{Q_s}) \\ &= \textstyle\sum_j P(t_i \mid s_j, \theta_{Q_s}) P(s_j \mid \theta_{Q_s}) \\ &\approx \textstyle\sum_j t(t_i \mid s_j) P(s_j \mid \theta_{Q_s}) \end{aligned}$$

where *t* is a term in document (target) language; *s* in query (source) language; $t(t_i|s_j)$ is translation model.



3. Using different indexing units

Different indexing units

- Single index
  - Unigram (single character)
  - Bigram
  - Word

“国企研发投资”
U: 国/企/研/发/投/资
B: 国企/企研/研发/发投/投资
W: 国企/研发/投资

$$Score(D,Q) = -KL(\theta_Q \parallel \theta_D)$$

- Problems with single index
  - Words can be segmented in different ways
  - Closely related words cannot match

Combining different indexes

- Combine words with characters or bigrams and characters
  - Merging indexes
    - WU: Word & Unigram
    - BU: Bigram & Unigram

“国企研发投资”
WU: 国企/研发/投资/国/企/研/发/投/资
BU: 国企/企研/研发/发投/投资/国/企/研/发/投/资

  - Multiple indexes
    - B+U: Interpolate Bigram and Unigram

$$\begin{tikzcd}
 & Q_U \arrow[r] & -KL(Q_U,D_U) & D_U \arrow[l] & \\
Q \arrow[ur] \arrow[dr] & & & & D \arrow[ul] \arrow[dl] \\
 & Q_B \arrow[r] & -KL(Q_U,D_U) & D_B \arrow[l] &
\end{tikzcd}$$

$$Score(D,Q) = \sum_i \alpha_i Score_i(D,Q)$$

Experiment Setting

	NTCIR3/4		NTCIR5/6	
	Collections	#doc (KB)	Collections	#doc(KB)
Cn	CIRB011 CIRB020	381	CIRB040r	901
Jp	Mainichi98/99 Yomiuri98+99	594	Mainichi00/01r Yomiuri00+01	858
Kr	Chosunilbo98/99 Hankookilbo	254	Chosunilbo00/01 Hankookilbo00/01	220

	NTCIR3	NTCIR4	NTCIR5	NTCIR6
Numbers of topics	50	60	50	50

Using different index units for C/J/K monolingual IR on NTCIR4/5

Run	Means Average Precision (MAP)											
	U		B		W		BU		WU		0.3B+0.7U	
	Rigid	Relax	Rigid	Relax	Rigid	Relax	Rigid	Relax	Rigid	Relax	Rigid	Relax
C-C-T-N4	.1929	.2370	.1670	.2065	.1679	.2131	.1928	.2363	.1817	.2269	**.1979**	**.2455**
C-C-T-N5	**.3302**	.3589	.2713	.3300	.2676	.3315	.2974	.3554	.3017	.3537	.3300	**.3766**
J-J-T-N4	.2377	.2899	.2768	.3670	–	–	.2807	**.3722**	–	–	**.2873**	.3664
J-J-T-N5	.2376	.2730	.2471	.3273	–	–	.2705	.3458	–	–	**.2900**	**.3495**
K-K-T-N4	.2004	.2147	.3873	.4195	–	–	**.4084**	**.4396**	–	–	.3608	.3889
K-K-T-N5	.2603	.2777	.3699	.3996	–	–	**.3865**	**.4178**	–	–	.3800	.4001

- Surprisingly, U is better than B and W for Chinese
- Interpolating unigram and bigram (B+U) has the best performance for Chinese and Japanese.
- However, BU and B are the best for Korean.

Analysis of monolingual IR results

- NTCIR 5 Topic 18
  - 烟 草 商 诉 讼 赔 偿 (Tobacco business, accusation, compensation)
  - **Word:** 烟草商(Tobacco business) 诉讼(accusation) 赔偿(compensation)
  - Unigram (0.7659) > Word(0.1625)
  - The relevant document *udn_xxx_20000716_0463237* includes 烟草,公司,业者, 香烟 ,烟商, but cannot match “烟草商”.
    It’s ranked 4th with unigram index, but 62nd with word index.
- NTCIR 5 Topic 24
  - 经 济 舱 综 合 症 候 群 航 班 (Economy class, syndrome, flight)
  - **Word:** 经济(economy) 综合症(syndrome) 候(wait) 航班(flight)
  - Ubigram(.7607)>Word(0.0002)
  - “..综合症候..” is segmented into “../综合症/候/..”
    It cannot match “症候” (syndrome).
  - The irrelevant document *udn_xxx_20011227_1251132* is retrieved only due to 综合症.
- The combination of unigrams with words or bigrams help solve these problems

The results of CJK monolingual IR on NTCIR6

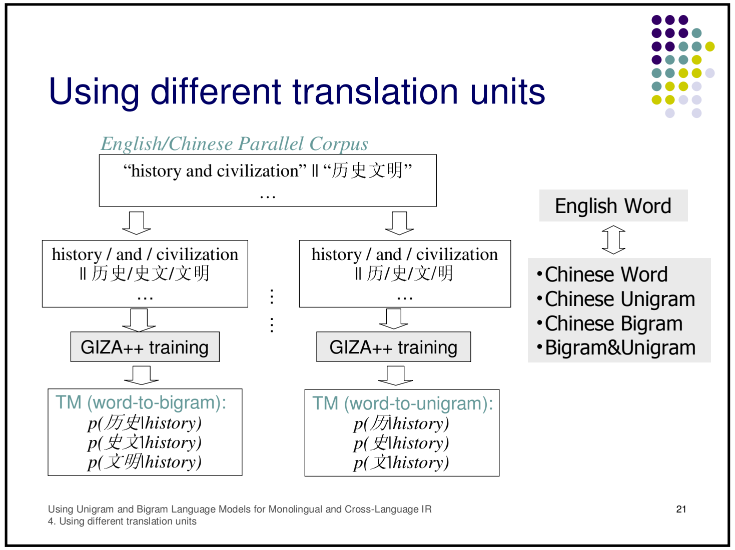
Run-id	RALI without pseudo feedback		RALI with pseudo feedback		Average MAP of all NTCIR6 runs	
	Rigid	Relax	Rigid	Relax	Rigid	Relax
C-C-T	.2139	.3022	.2330	.3303	.2269	.3141
C-C-D	.1671	.2376	.2031	.2907	.2354	.3294
J-J-T	.2426	.3171	.2576	.3343	.2707	.3427
J-J-D	.1877	.2485	.2292	.3052	.2480	.3214
K-K-T	.3332	.3939	.3460	.4130	.3833	.4644
K-K-D	.2623	.2970	.3287	.3945	.3892	.4678

- Our submission: Chinese&Japanese: U+B; Korean K-K-T:BU, K-K-D:U
- Our results are lower than average MAPs of NTCIR6:
  - We only aimed to compare index units using the basic IR technique
  - After apply a simple pseudo relevance feedback the results become more comparable to average MAPs.
- Globally, combining n-grams is a reasonable alternative to word segmentation
- (This is not new.)

4. Using different translation units

Existing approaches

- Translating English words to Chinese words
- Possibly cutting Chinese words into n-grams
- Then monolingual retrieval in Chinese
- Problem:
  - Coverage of Chinese words in the linguistic resources (dictionary, parallel corpus)
  - Variation of spelling in Chinese
  - Possible solution: also translating into n-grams ?



Using different translation units

English/Chinese Parallel Corpus

"history and civilization" ǁ "历史文明"
…

history / and / civilization
ǁ 历史/史文/文明
…

GIZA++ training

TM (word-to-bigram):
p(历史|history)
p(史文|history)
p(文明|history)

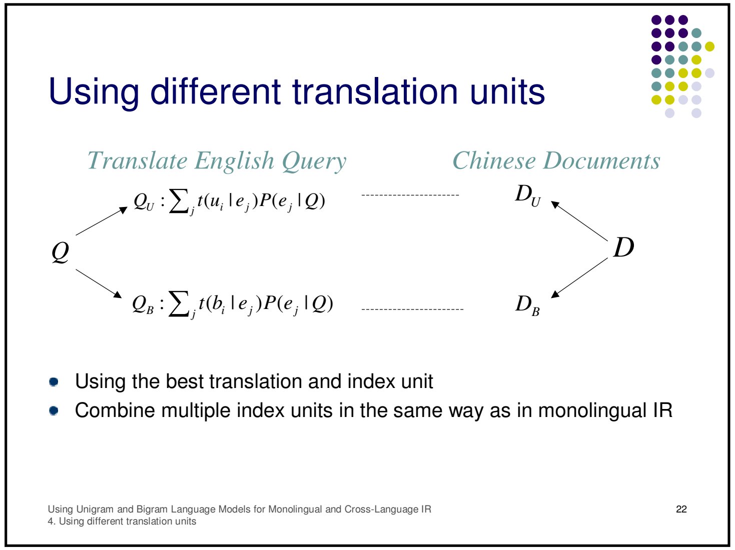
history / and / civilization
ǁ 历/史/文/明
…

GIZA++ training

TM (word-to-unigram):
p(历|history)
p(史|history)
p(文|history)

English Word

- Chinese Word
- Chinese Unigram
- Chinese Bigram
- Bigram&Unigram



Using different translation units

Translate English Query

Chinese Documents

Q

$Q_U : \sum_j t(u_i \mid e_j) P(e_j \mid Q)$

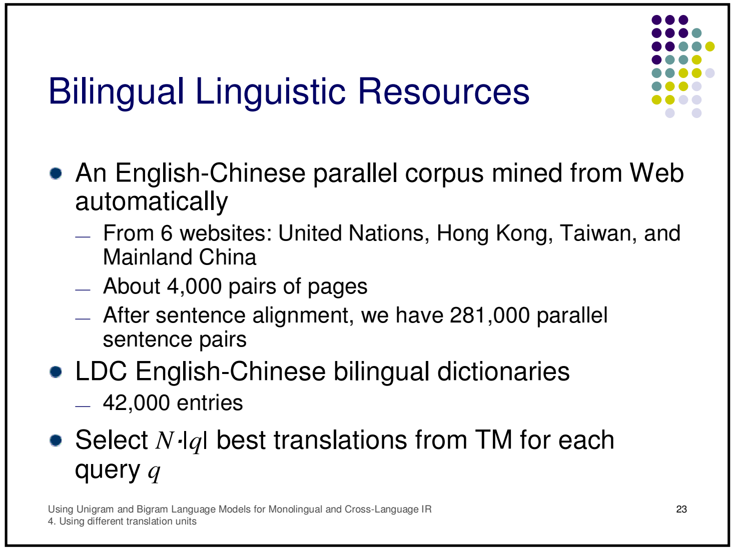
$Q_B : \sum_j t(b_i \mid e_j) P(e_j \mid Q)$

D_U

D_B

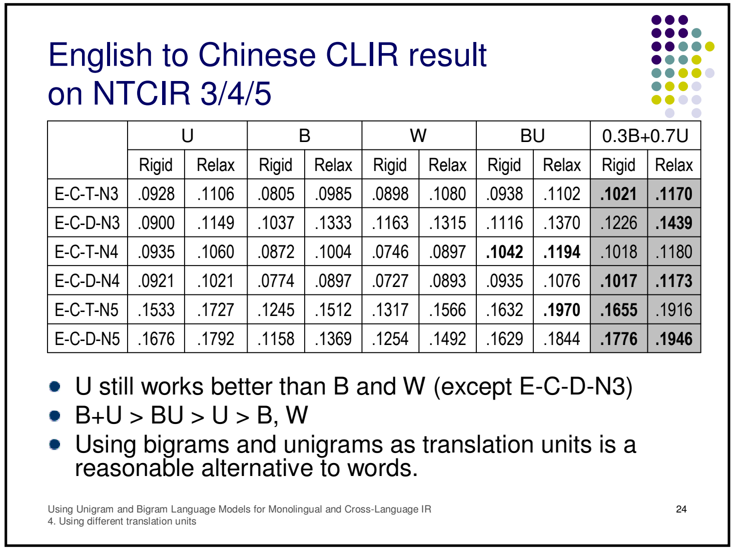
D

- Using the best translation and index unit
- Combine multiple index units in the same way as in monolingual IR



Bilingual Linguistic Resources

- An English-Chinese parallel corpus mined from Web automatically
  - From 6 websites: United Nations, Hong Kong, Taiwan, and Mainland China
  - About 4,000 pairs of pages
  - After sentence alignment, we have 281,000 parallel sentence pairs
- LDC English-Chinese bilingual dictionaries
  - 42,000 entries
- Select $N \cdot |q|$ best translations from TM for each query q



English to Chinese CLIR result on NTCIR 3/4/5

	U		B		W		BU		0.3B+0.7U	
	Rigid	Relax	Rigid	Relax	Rigid	Relax	Rigid	Relax	Rigid	Relax
E-C-T-N3	.0928	.1106	.0805	.0985	.0898	.1080	.0938	.1102	**.1021**	**.1170**
E-C-D-N3	.0900	.1149	.1037	.1333	.1163	.1315	.1116	.1370	.1226	**.1439**
E-C-T-N4	.0935	.1060	.0872	.1004	.0746	.0897	**.1042**	**.1194**	.1018	.1180
E-C-D-N4	.0921	.1021	.0774	.0897	.0727	.0893	.0935	.1076	**.1017**	**.1173**
E-C-T-N5	.1533	.1727	.1245	.1512	.1317	.1566	.1632	**.1970**	**.1655**	.1916
E-C-D-N5	.1676	.1792	.1158	.1369	.1254	.1492	.1629	.1844	**.1776**	**.1946**

- U still works better than B and W (except E-C-D-N3)
- B+U > BU > U > B, W
- Using bigrams and unigrams as translation units is a reasonable alternative to words.

Analysis of CLIR result

- NTCIR5 Topic 18: Tobacco business, accusation, compensation (烟草商，訴訟，賠償)
- MAP(BU)=0.1164 > MAP(W)=0.0044
  - Query translated by Bigram&Unigram TM:

偿 0.2601	**烟 0.2531**	**补偿 0.2127**	**补 0.2018**
业 0.1788	烟酒 0.1254	**商 0.1121**	**偿贸 0.1042**
指 0.0930	及 0.0926	**控 0.0795**	**企 0.0641**
企业 0.0639	**告 0.0638**	经 0.0602	**赔偿 0.0553**
草 0.0547	的指 0.0545	**赔 0.0537**	**指控 0.0497**
烟草 0.0484	务 0.0408	…	

  - Query translated by Word TM

补偿贸易 0.3523	烟酒 0.3453	**补偿 0.3349**	**企业 0.1923**
赔偿 0.1772	**指控 0.1558**	**烟草 0.1260**	公卖 0.1018
商务 0.0944	**经营 0.0877**	创业 0.0801	生意 0.0797
商 0.0778	用品 0.0728	**指责 0.0618**	业务 0.0547
至于 0.0540	商业 0.0536	台商 0.0476	报告 0.0462
事业 0.0456	组织 0.0415	…	

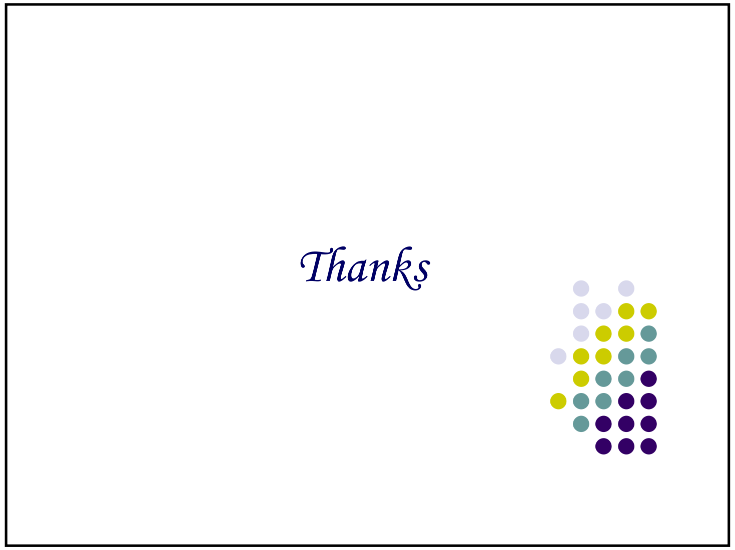
5. Conclusion and future work

Conclusion

- Our experimental results show that n-grams are generally as effective as words for monolingual and Cross-language IR in Chinese. For Japanese and Korean, n-grams approaches are comparable to the average results of NTCIR6.
- We tested creating different types of index separately, then grouping them during the retrieval process. We found that this approach is slightly more effective for Chinese and Japanese.
- Overall, n-grams can be interesting alternative indexing and translation units to word.

Future work

- We noticed that a type of index unit has variable effectiveness for different queries.
- Not reasonable to assign the same weight to a type of index for all queries
- Future work:
  - Make the weight dependent on query words.
  - Better parameter tuning methods



Thanks