

Translating Unknown Words by Analogical Learning

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The Problem we Address

Translating unknown words

\mathcal{L} , seed lexicon	
lucide	↔ clear-thinking, blind, refocussed, lucid, far-sighted
lucidité	↔ well-informed, meticulously, moderation, penetrating lucidity, clear-headed, clear-sighted
futile	↔ meaningless, futile
faillites	↔ bankruptcies, bankruptcy
faillite	↔ collapse, bust, insolvency, ruin, complaining, wall, business, bankruptcy, bankrupt

futilité ?

Existing Solutions to Translating Unknown Entities

- Translating proper-names [Chen et al., 1998] and named-entities [Al-Onaizan and Knight, 2001]
↪ ANALOG is complementary to those approaches
- Paraphrasing unknown entities by making use of massive homogeneous bitexts [Callisson-Burch et al., 2006 ; Cohn and Lapata, 2007]
↪ ANALOG requires only a **seed** lexicon (+ target-language lexicon)
- Identifying translations in **comparable corpora** [Fung and Yee, 1998 ; Rapp,1999 ; Tanaka, 1999]
↪ ANALOG requires only a **seed** lexicon (+ target-language lexicon)

Other (more) Popular Solutions to Translating Unknown Words

- Removing unknown (source) words before translating
- Leaving unknown-words untranslated

Our approach :

Translating unknown-words by analogy

Overview

Motivations

Analogical Learning

Introduction

Principle

Bilingual Lexicon Enrichment

Practical Issues

Experiments

Protocol

Results

Discussion

Proportional Analogy

$$[A : B = C : D]$$

“A is to B as C is to D”

(See for instance [Chiu et al., 2007])

Formal Analogies

Examples taken from (Lepage, 1998)

- Formal **analogical proportions** :

honor : honōrem	=	ōrātor : ōrātōrem
reader : unreadable	=	doer : undoable
répression : répressionnaire	=	réaction : réactionnaire
tinggal : ketinggalan	=	duduk : kedudukan

- Formal **analogical equation** :

[*lang* : *längste* = *scharf* : ?]

Formal Analogies

Examples taken from (Lepage, 1998)

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reader : unreadable	=	doer : undoable
répression : répressionnaire	=	réaction : réactionnaire
tinggal : ketinggalan	=	duduk : kedudukan

- Formal **analogical equation** :

[*lang* : *längste* = *scharf* : *schärfste*]

Principle

Stroppa & Yvon, 2005

\mathcal{L} : training corpus

\mathcal{I} : input space (defined by a set of features over \mathcal{L})

\mathcal{O} : output space (defined by a set of features over \mathcal{L})

X : incomplete observation (the input features are known)

1. Build $\mathcal{E}_{\mathcal{I}}(X)$:

$$\{(A, B, C) \in \mathcal{L}^3 \mid [I(A) : I(B) = I(C) : I(X)]\}$$

2. Build $\mathcal{E}_{\mathcal{O}}(X)$:

$$\{Y \mid [O(A) : O(B) = O(C) : Y], \forall (A, B, C) \in \mathcal{E}_{\mathcal{I}}(X)\}$$

3. Choose $O(X)$ among $\mathcal{E}_{\mathcal{O}}(X)$.

where $I(X)$ and $O(X)$ stand for the projection of X into the input and output space respectively.

Bilingual Lexicon Enrichment

Step-1 : computing $\mathcal{E}_I(\text{futilité})$

futilité ?

Bilingual Lexicon Enrichment

Step-1 : computing $\mathcal{E}_I(\text{futilité})$

faillites

faillite

futilité ?

futilités

[*faillites : faillite = futilités : **futilité***]

Bilingual Lexicon Enrichment

Step-1 : computing $\mathcal{E}_I(\text{futilité})$

faillites

futile

faillite

futilité ?

futilités

lucide

lucidité

[*lucide* : *lucidité* = *futile* : **futilité**]

Bilingual Lexicon Enrichment

Step-1 : computing $\mathcal{E}_I(\text{futilit })$

faillites

futile

faillite

hostilit s

futilit  ?

hostiles

futilit s

lucide

lucidit 

$[hostiles : hostilit s = futile : \text{futilit }]$

Bilingual Lexicon Enrichment

Step-1 : computing $\mathcal{E}_I(\text{futilité})$

faillites

réalités

faillite

futilités

futilités

lucide

futile

réalité

hostilités

hostiles

futilité ?

lucidité

$[réalités : réalité = futilités : \text{futilité}]$

Bilingual Lexicon Enrichment

Step-1 : computing $\mathcal{E}_T(\text{futilité})$

faillites	brutale		futile
réalités	brutalité	réalité	mutilé
faillite		bestialité	hostilités
futilités	futilité ?		natalité
facile		facilités	hostiles
futilités	bestiale	timide	natale
lucide	faillite		maille
	timidité	lucidité	

2944 analogical equations, 84 valid stems

Bilingual Lexicon Enrichment

Step-1 : computing $\mathcal{E}_T(\text{futilité})$

⟨activités, activité, futilités⟩ ⟨fatale, futile, fatalité⟩ ⟨timide, timidité, futile⟩
 ⟨faciles, facilités, futile⟩ ⟨cupide, cupidité, futile⟩ ⟨utilisés, futilités, utilisé⟩
 ⟨humide, humidité, futile⟩ ⟨brutalités, brutalité, futilités⟩ ⟨multipliés, multiplié, futilités⟩
 ⟨qualités, qualité, futilités⟩ ⟨totale, totalité, futile⟩ ⟨utilisés, utilisé, futilités⟩
 ⟨mutilés, mutilé, futilités⟩ ⟨félicités, futilités, félicité⟩ ⟨active, activité, futile⟩
 ⟨mature, maturité, futile⟩ ⟨unités, futilités, unité⟩ ⟨habilités, habilité, futilités⟩
 ⟨fragile, fragilité, futile⟩ ⟨subtile, subtilité, futile⟩ ⟨mutilés, futilités, mutilé⟩
 ⟨autorités, autorité, futilités⟩ ⟨vitale, vitalité, futile⟩ ⟨autorisés, autorisé, futilités⟩
 ⟨maille, faillite, mutilé⟩ ⟨mute, mutilé, futile⟩ ⟨facultés, faculté, futilités⟩
 ⟨félicités, félicité, futilités⟩ ⟨utile, futile, utilité⟩ ⟨facilités, facilité, futilités⟩
 ⟨rurale, ruralité, futile⟩ ⟨brutalités, futilités, brutalité⟩ ⟨finales, finalités, futile⟩
 ⟨subtiles, subtilités, futile⟩ ⟨spatiale, spatialité, futile⟩ ⟨visités, visité, futilités⟩
 ⟨réalités, réalité, futilités⟩ ⟨pénale, pénalité, futile⟩ ⟨brutales, brutalités, futile⟩
 ⟨habilités, futilités, habilité⟩ ⟨hostilités, futilités, hostilité⟩ (+ 42 others ...)

Bilingual Lexicon Enrichment

Step-2 : computing $\mathcal{E}_O(\text{futilité})$

[*faillites* : *faillite* = *futilités* : **futilité**]

faillites	↔	bankruptcies , bankruptcy
faillite	↔	collapse, bust, insolvency, ruin, complaining, bankrupt, business, bankruptcy , wall
futilités	↔	trivialities

[*bankruptcies* : *bankruptcy* = *trivialities* : ?] { **triviality** }

Bilingual Lexicon Enrichment

Step-2 : computing $E_O(\text{futilité})$

[*lucide* : *lucidité* = *futile* : **futilité**]

lucide	↔	clear-thinking, blind, refocussed, lucid, far-sighted
lucidité	↔	well-informed, meticulously, moderation, penetrating, lucidity, clear-headed, clear-sighted
futilité	↔	meaningless, futile

[*lucid* : *lucidity* = *meaningless* : ?] { *meaninglessness* }

[*lucid* : *lucidity* = *futile* : ?] { *futiityle*, *futileity*, *futilitye* }

[*far-sighted* : *clear-sighted* = *futile* : ?] { *fucleile*, *cleutile*,
clefuile, *cluteile*, *culetile*, *cluetile*, *cfuleile*, *clfueile*, *cutleile* }

Bilingual Lexicon Enrichment

Step-3 : choosing from \mathcal{E}_O (futilité)

1124 \neq forms generated, 120 seen at least twice

(trivialities,27)	(meaninglitiesss,3)	(meaniitnglyss,2)
(triviality,14)	(meaningiltyss,2)	(superfluous,2)
(futile,9)	(futiilty,2)	(meaningitilesss,2)
(futilitye,9)	(applicatitrivialitis,2)	(meaningitlyss,2)
(meaningless,9)	(futiitiles,2)	(meaninglesity,2)
(meaninglityess,8)	(futiitly,2)	(meaninglessness,2)
(trivialitie,6)	(futiityl,2)	(meaninglityes,2)
(futility,4)	(futileity,2)	(meaninigtyss,2)
(meaninglityss,4)	(futileessne,2)	(meaninitglyss,2)
(futilities,3)	(high-triviality,2)	(meaninitiglesss,2)
(meaninglesit,3)	(ltbbyirivialitig,2)	(mfaninglecilits,2)

Bilingual Lexicon Enrichment

Step-3 : choosing from \mathcal{E}_0 (futilité)

1124 \neq forms generated, 120 seen at least twice

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Bilingual Lexicon Enrichment

Step-3 : choosing from \mathcal{E}_O (futilité)

13 solutions kept

(trivialities,27) (triviality,14) (futile,9)
(meaningless,9) (futility,4) (meaninglessness,3)
(superfluous,2) (unwieldy,2) (unnecessary,2)
(uselessness,2) (trivially,1) (tie,1) (trivial,1)

Analogical Equation Solver

[Lepage, 1998]

Introduction Apprentissage Analogique Expériences Discussion

[even : usual = unevenly : ?]

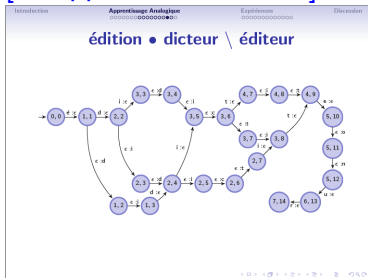
A	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B	C	U	N	E	V	E	N	L	Y	

(N,L,Y, [SUB,DEL], MOVE C + COPY Y)

U	S	U	A	E	V	E	N	E	V	E	N
L											

U N E V E N L Y

[Stroppa & Yvon, 2005]



- We implemented the algorithm of [Lepage, 1998]

Practical Issues

- Computing

$\mathcal{E}_{\mathcal{I}}(\text{UNK}) = \{(A, B, C) \in \mathcal{I}^3 / [A : B = C : \text{UNK}]\}$ is an operation **cubic** in $|\mathcal{I}|$.

↪ generative search : $A, B \in \mathcal{I}^2$ and $C \in [B : A = \text{UNK} : \diamond]$

↪ heuristic : $A \in v_{\delta}(\text{UNK})$ et $B \in v_{\beta}(A)$ with :

$$v_{\gamma}(X) = \{Y \mid d(X, Y) \leq \gamma\}$$

- The number of lowest-cost paths is potentially exponential in the length of the sequences to align

↪ synchronize at most M^2 paths ($M=20$)

- Analogical solver “imperfect”

↪ filter with a target lexicon \mathcal{V} of 466 439 entries

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Resources from WMT'06

[Koehn et Monz, 2006]

UNK-words in the test set (French → English) :

- 20% of proper names
- 12% of numerical expressions (years, page numbers, etc.)
- 8% of compound-words
- 4% of borrowed-word (latin, greek)

~ **54% of ordinary words**

Protocol

- \mathcal{L}_T : **seed lexicon**
IBM model 2 (s2t \cap t2s models), trained on the T first pairs of sentences of TRAIN.
 $\hookrightarrow T : 5\,000, 10\,000, 100\,000, 200\,000, \text{ and } 500\,000$
 - \mathcal{L}_{ref} : **reference lexicon**
IBM model 2 (s2t \cap t2s models), trained on TRAIN.
 - Translate with ANALOG non-numerical words of TEST, present in \mathcal{L}_{ref} , **but** unknown of \mathcal{L}_T
 - Two measurements :
 - recall** % of words with at least one translation (good or not)
 - precision** % of words translated for which at least one translation is sanctioned by \mathcal{L}_{ref}
- ! !unusual ! !**

Baseline approaches

X \equiv unknown word

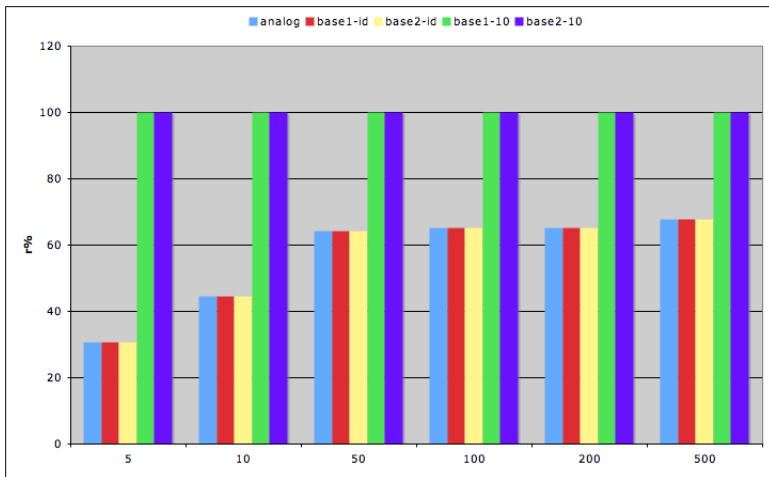
base1 $\hat{T} = \operatorname{argmin}_{T \in \mathcal{O}} \operatorname{edit}\text{-dist}(T, X)$

signalaient \rightarrow *signalling, signalled, salient, ...*

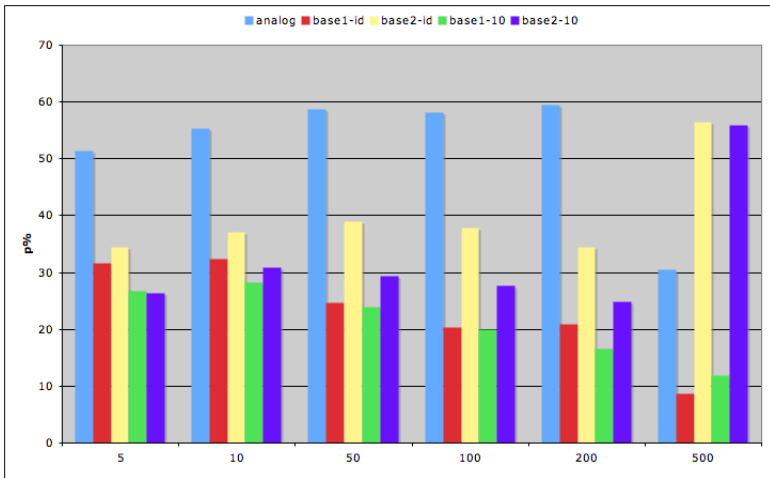
base2 $\hat{T} = \operatorname{argmax}_{S \in V(X)} \operatorname{proj}_{\mathcal{L}}(S)$ où
 $V(X) = \operatorname{argmin}_{S \in \mathcal{I}} \operatorname{edit}\text{-dist}(X, S)$

signalaient \rightarrow *signalement, signeraient, signalent, ...*
 \rightarrow *indicates, sign, signalling, ...*

Recall rates (French→English)



Precision rates (French→English)



Case of $T = 500\,000$ (French \rightarrow English)

in-domain

- Only a few words seen in \mathcal{L}_{ref} , but not in $\mathcal{L}_{500\,000}$
 - 34 words (in-domain), 1.2 translations sanctioned by \mathcal{L}_{ref}
 - $\sim 1/3$ of the reference translations are wrong
- Ex : **perquisitions** :

A	(seizures,76)	(seizure,17)	(raid,1)
\mathcal{L}_{ref}	house-to-house		

- Ex : **non-discriminatoire** :

A	(non-discriminatory,72)	(non-discrimination,47)
	(nondiscrimination,24)	(nondiscriminatory,23)
	(outlawing,20)	(race,20)
	(prosperity,20)	(antidiscrimination,20)
	(anti-discrimination,18)	(discrimination,17)
\mathcal{L}_{ref}	affirmative	

Manual Evaluation

contournant (49 candidates)

A ◇ **(circumventing,55)** (undermining,20) (evading,19)
 (circumvented,17) (overturning,16) (circumvent,15) (circumvention,15) (bypass,13) (evade,13) (skirt,12) ...

\mathcal{L}_{ref} ◇ **skirting, bypassing**, by-pass, overcoming

- 80% of **ordinary words** receive a valid translation in first-position by ANALOG
- Only 35% in the case of B2

Impact on translation (into English)

- Extension of the phrase table with the first translation produced for each unknown word by ANALOG (seed lexicon = \mathcal{L}_{ref})

	French		Spanish		German	
	WER	BLEU	WER	BLEU	WER	BLEU
base	61.8	22.74	54.0	27.00	69.9	18.15
+A	61.6	22.90	53.7	27.27	69.7	18.30
sentences	387		452		814	

↪ consistent but non-significant gains with ANALOG

Translating phrases

French → English

expulsent ◇ (expelling,36) (expel,31) (are expelling,23)
(are expel,10)

focaliserai ◇ (focus,10) (focus solely,9) (concentrate all,9)
(will focus,9) (will placing,9)

dépasseront ◇ (will exceed,4) (exceed,3) (will be ex-
ceed,3) (we go beyond,2) (will be exceeding,2)

non-réussite de ◇ (lack of success for,4) (lack of success
of,4) (lack of success,4)

que vous **subissez** ◇ (you are experiencing,2)

- $\mathcal{L}_{ref}, \mathcal{L}_T$: phrase tables
- Precision : 55%
- Low recall : 10% (too much filtering during step-1)

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Conclusion

- Analogical learning allows to translate correctly $\sim 80\%$ of ordinary unknown-words (French \rightarrow English)
- Performance higher than fair baselines
- No knowledge required or external resources
- Performance \sim stable over language pairs
- Not contrived to translate only words

Future Work

- Testing the **systematic** enrichment of a statistical phrase-table (unknown and unfrequent words or phrases)
- Weighting analogies (currently all analogies are considered equally good)
- Comparing ANALOG to other approaches exploiting morphology-related information in SMT [Nießen, 2002 ; Popović and Ney, 2004, Goldwater and McClosky, 2005 ; Lee, 2004, Sadat and Habash, 2006]
- Comparing ANALOG to unsupervised morphology-acquisition techniques [GoldSmith, 2001 ; Baldwin, 2005 ; Freitag 2005]

$[do : you = have : ?]$

[even : usual = unevenly : ?]

Property (Stroppa and Yvon, 2005)

$$[x : y = z : t] \iff t \in (y \bullet z) \setminus x$$

$$\text{usual} \bullet \text{unevenly} = S = \{\text{unusevualenly}, \text{uneusveunlaly}, \dots\}$$

$$S \setminus \text{even} = \{\text{unusually}, \text{unusulaly}, \dots\}$$

[Lepage, 1998]

15 solutions

[Stroppa & Yvon, 2005]

72 solutions

$$\left\{ \begin{array}{lll} uunusually & usuaunlly & usuunalyl \\ \text{unusually} & usunually & uunslyual \\ unulyusual & uunusuallyl & unuslyual \\ unusuallyl & usunuallyl & uunsulyal \\ unusulyal & usunulyal & usuunally \end{array} \right\}$$

Manual Evaluation of 142 words

freq < 4, $\mathcal{L}_{200,000}$, (French→English)

		ANALOG			
		GOOD	WRONG	SILENT	
IBM	GOOD	59	2	22	83
	WRONG	41	3	15	59
		100	5	37	142

- $\sim 42\%$ of the words receive a wrong associations by IBM model 2 ($\sim 4\%$ with ANALOG)
- $\sim 70\%$ of these wrongly translated words receive by ANALOG a valid translation

Performances among language pairs

in-domain

T	French		Spanish		German	
	p%	r%	p%	r%	p%	r%
5	51.4	30.7	52.8	30.3	49.3	23.1
10	55.3	44.4	52.0	45.2	47.6	33.3
50	58.8	64.3	54.0	66.5	44.6	53.2
100	58.2	65.1	53.9	69.1	45.8	55.6
200	59.4	65.2	46.4	71.8	43.0	59.2

- $\sim 10\%$ decrease for German \rightarrow English
- decrease in precision for $T = 200\ 000$ in Spanish and German

Resources

- WMT'06 [Koehn et Monz, 2006] : French, Spanish, German \leftrightarrow English

	French		Spanish		German	
$ sent _{train}$	688 031		730 740		751 088	
$ voc _{train}$	80 343		100 435		186 231	
test-	in	out	in	out	in	out
$ sent _{test}$	2 000	1 064	2 000	1 064	2 000	1 064
$ voc _{test}$	7 230	5 263	7 719	5 322	8 812	6 067
$ unknown $	180	265	233	292	469	599
oov%	0.26	1.22	0.38	1.37	0.84	2.87

$$[x : y = z : t]$$

Propriété (Stroppa et Yvon, 2005)

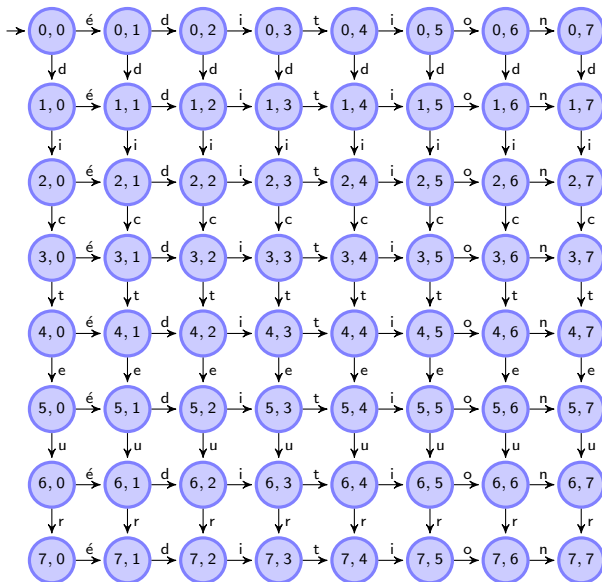
$$[x : y = z : t] \iff t \in (y \bullet z) \setminus x$$

Calculable par composition de deux transducteurs :

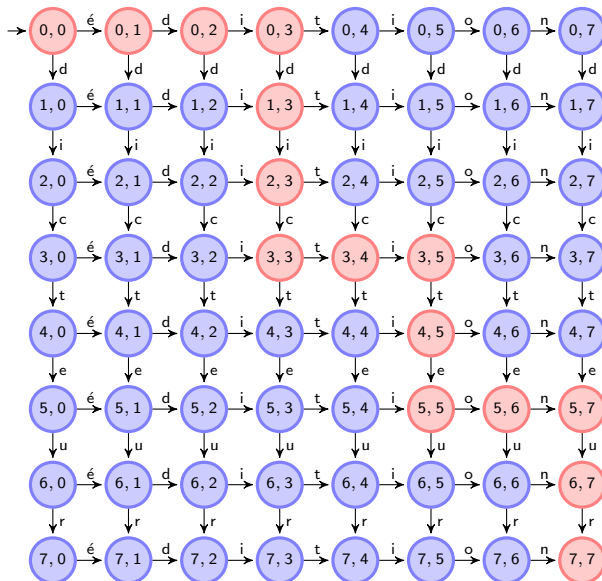
shuffle $a \bullet b$ composition de sous-séquences de a et b en respectant l'ordre des symboles dans chaque séquence

complémentaire $a \setminus b$ retrait dans a des symboles de b , de la gauche vers la droite

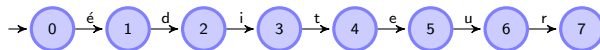
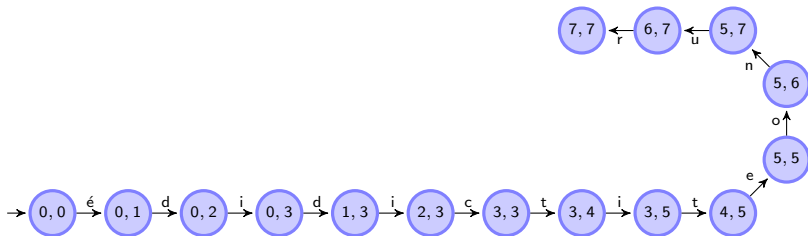
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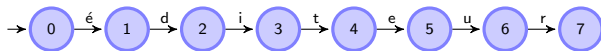
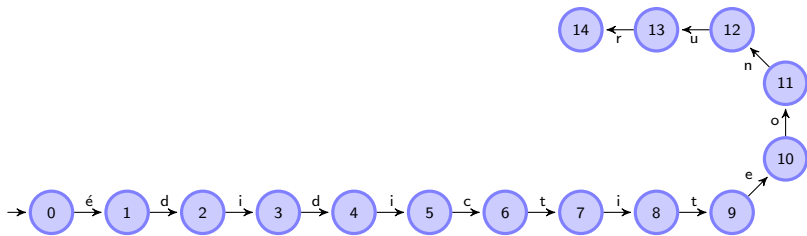
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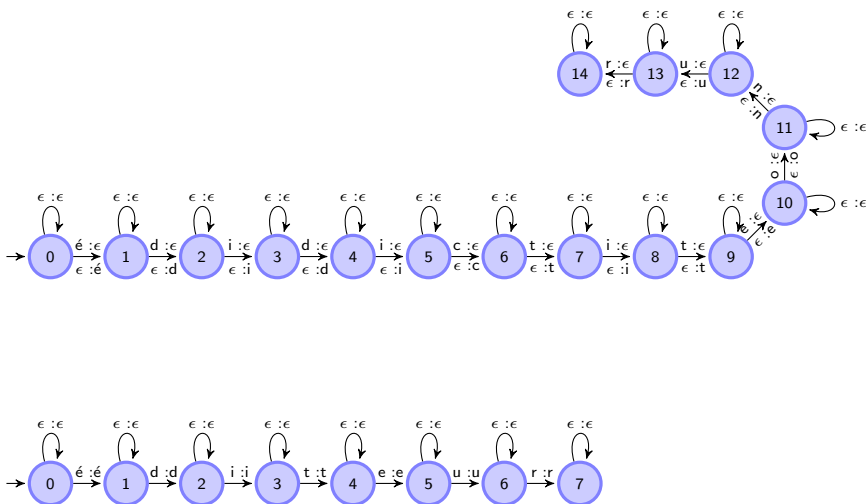
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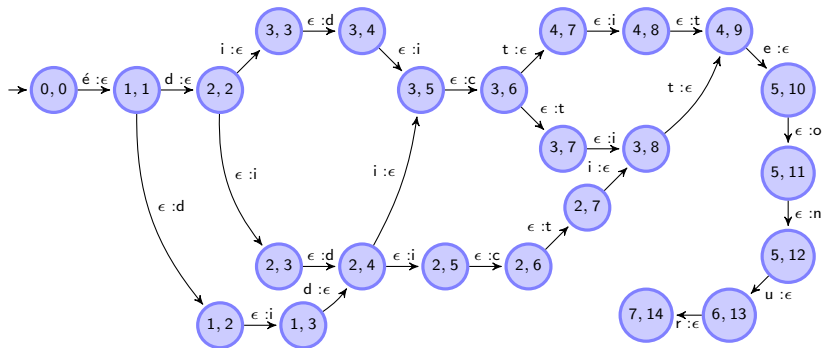
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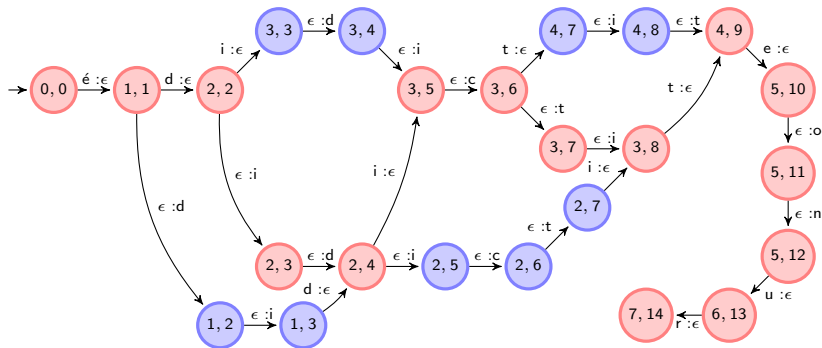
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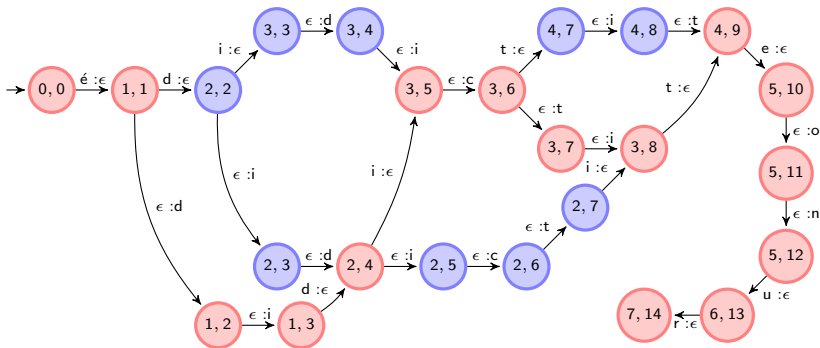


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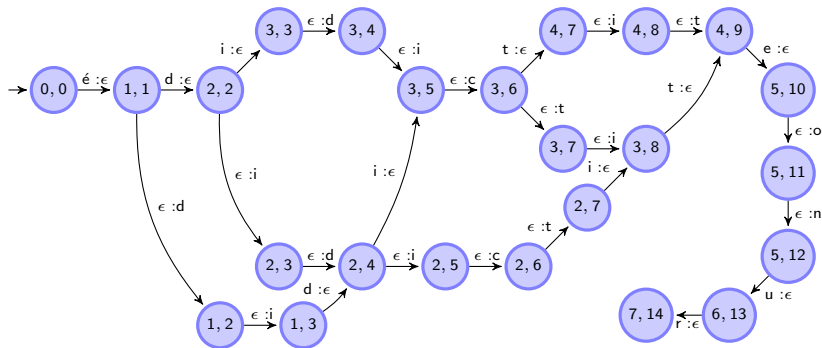
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idction , **diction**

édition • dicteur \ éditeur



idction , diction , idiction, diicton, diciton

[éditeur : édition = dicteur : diction]

110 sol. $f(\text{diction}) = 5180, f(\text{ditcion}) = 1155, \dots, f(\text{tiondic}) = 1$

diction ditcion dcition diticon diciton diicton diitcon idction
 ditioen diciotn cdition dticion dtiicon diicotn diioctn icdtion
 dction idtcion idticon itdicon ditionc dicient diitocn idcition
 dciiton dtiioen idiction iditcon diicont diioent diionct ditionc
 idtioen itdcion tdicion dtioien itdioen tdiicon dioictn icdicion
 dciioen cdtiion ctdiion ictdion idciotn itidcon tidicon diitonc
 dtiionc idicotn idioctn cdiiton iditocn itdoien itidocn tdiioen
 idtionc dioient dioinct dionict ditionc ditonic itdionc dciiont
 dtioien dtionic idciont idtoien itioden itodien tdioien tidioen
 tidoien tiodien cdiioen icdiotn idoictn iodictn idicent idioent
 idionct itidonc iditonc itdoien itdonic itiodnc tdiionc dciiont
 icdiont idoient idoint idonict idtoien idtonic iodient iodinct
 iodnict iondict itiondc itodien itodnic itondic tdioien tdionic
 tidionc tidoien tidonic tiodien tiodnic tiondic

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y
△															△

$\langle N, L, Y, [SUB, DEL], MOVE C + COPY Y \rangle$

				E	V	E	N
U	S	U	A				L

△

				E	V	E	N
U	N	E	V	E	N	L	Y

△

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y

$\langle N, L, L, [\text{SUB}, \text{DEL}], \text{MOVE } C + \text{COPY } L \rangle$

				E	V	E	N
U	S	U	A				L

				E	V	E	N
U	N	E	V	E	N	L	Y

Y

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B	C	U	N	E	V	E	N	L	Y	



$\langle N, L, N, [\text{SUB}, \leq \Rightarrow], \text{MOVE } A, B, C + \text{COPY } L \rangle$

				E	V	E	N
U	S	U	A				L



				E	V	E	N
U	N	E	V	E	N	L	Y



LY

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E<	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y



$\langle E, A, E, [INS, \langle = \rangle], MOVE B, C \rangle$

				E	V	E	N
U	S	U	A				L



				E	V	E	N
U	N	E	V	E	N	L	Y



LLY

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V<	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y



$\langle v, A, v, [\text{INS}, \langle = \rangle], \text{MOVE } B, C \rangle$

				E	V	E	N
U	S	U	A				L



				E	V	E	N
U	N	E	V	E	N	L	Y



LLY

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E<	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y



⟨E,A,E, [INS,<=>], MOVE B,C ⟩

				E	V	E	N
U	S	U	A				L



				E	V	E	N
U	N	E	V	E	N	L	Y



LLY

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A \triangleleft	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y
	\triangle							\triangle							

$\langle \epsilon, A, N, [\text{DEL}, \text{DEL}], \text{MOVE } C + \text{COPY } N \rangle$

				E	V	E	N
U	S	U	A				L
			\triangle				

		E	V	E	N		
U	N	E	V	E	N	L	Y
			\triangle				

LLY

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	
0	0	0	0	0	0	A \triangleleft	0	0	0	0	0	0	0	0	
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y
	\triangle						\triangle								

$\langle \epsilon, A, U, [\text{DEL}, \text{DEL}], \text{MOVE } C + \text{COPY } U \rangle$

				E	V	E	N
U	S	U	A				L
			\triangle				

				E	V	E	N
U	N	E	V	E	N	L	Y
			\triangle				

NLLY

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A \triangleleft	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y
\triangle						\triangle									

$\langle \epsilon, A, \epsilon, [\text{DEL}, \bullet], \text{MOVE B} + \text{COPY A} \rangle$

						E	V	E	N
U	S	U	A						L
\triangle									

						E	V	E	N
U	N	E	V	E	N	L	Y		
\triangle									

UNLLY

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y



$\langle \epsilon, U, \epsilon, [\text{DEL}, \bullet], \text{MOVE B} + \text{COPY U} \rangle$

						E	V	E	N
U	S	U	A						L



						E	V	E	N
U	N	E	V	E	N	L	Y		



AUNLLY

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A \triangleleft	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y

△

△

$\langle \epsilon, S, \epsilon, [\text{DEL}, \bullet], \text{MOVE B} + \text{COPY S} \rangle$

						E	V	E	N
U	S	U	A						L

△

						E	V	E	N
U	N	E	V	E	N	L	Y		

△

UAUNLLY

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A \triangleleft	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y

\triangle

\triangle

$\langle \epsilon, U, \epsilon, [\text{DEL}, \bullet], \text{MOVE B} + \text{COPY U} \rangle$

				E	V	E	N
U	S	U	A				L

\triangle

				E	V	E	N
U	N	E	V	E	N	L	Y

\triangle

SUAUNLLY

[even : usual = unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A◀	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y

△

△

 $\langle \epsilon, \epsilon, \epsilon, [\bullet, \bullet], \text{STOP} \rangle$

				E	V	E	N
U	S	U	A				L

△

		E	V	E	N		
U	N	E	V	E	N	L	Y

△

USUAUNLLY

[even : usual :: unevenly : ?]

4	4	4	4	4	4	N	4	4	3	3	2	1	0	0	0
3	3	3	3	3	3	E	3	3	3	2	1	0	0	0	0
2	2	2	2	2	2	V	2	2	2	1	0	0	0	0	0
1	1	1	1	1	1	E	1	1	1	0	0	0	0	0	0
0	0	0	0	0	0	A	0	0	0	0	0	0	0	0	0
L	A	U	S	U	B		C	U	N	E	V	E	N	L	Y



E				V		E	N
	U	S	U		A		L



		E	V	E	N		
U	N	E	V	E	N	L	Y



UNUSUALLY

[even : usual = unevenly : ◇]

15 solutions (681 synchronisations) :

$$\left\{ \begin{array}{lll} uunsually & usuaunlly & usuunalyl \\ \textit{unusually} & usunually & uunslyual \\ unulyusual & uunsualyl & unuslyual \\ unusualyl & usunualyl & uunsulyal \\ unusulyal & usunulyal & usuunally \end{array} \right\}$$

72 solutions avec la méthode de [\[Stroppa et Yvon, 2005\]](#)