



Machine Translation

01: Introduction

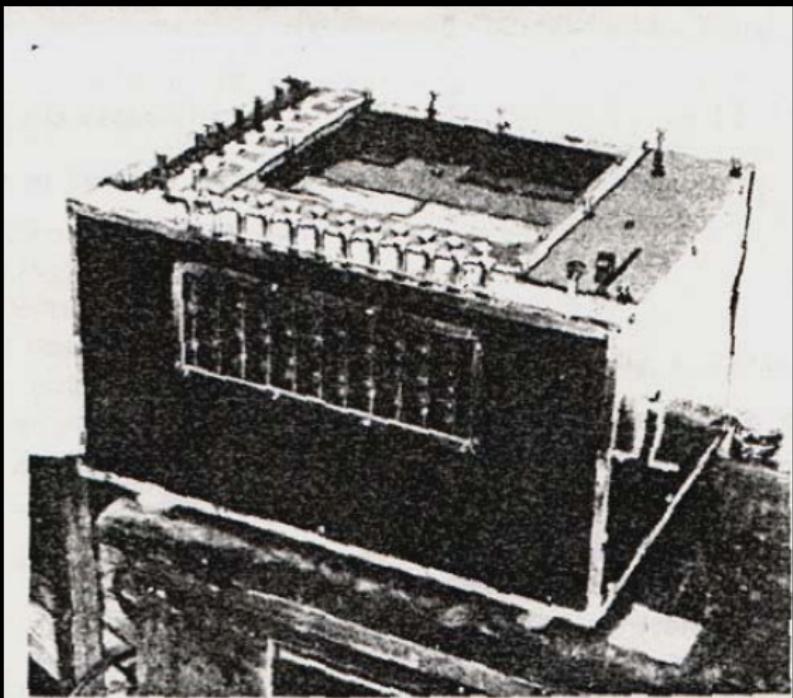
Rico Sennrich

(slide credit to Adam Lopez)

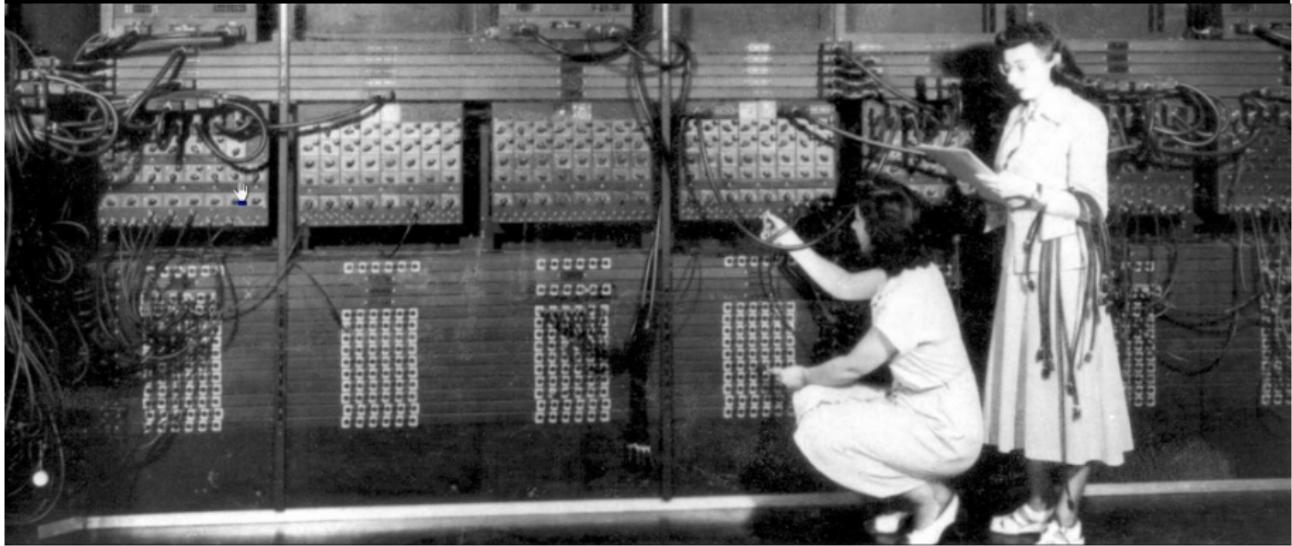
University of Edinburgh



The Confusion of
Tongues
Gustave Doré (1865)



Georges Artsrouni's "mechanical brain",
patented 1933 (France)



ENIAC (1946), first computer

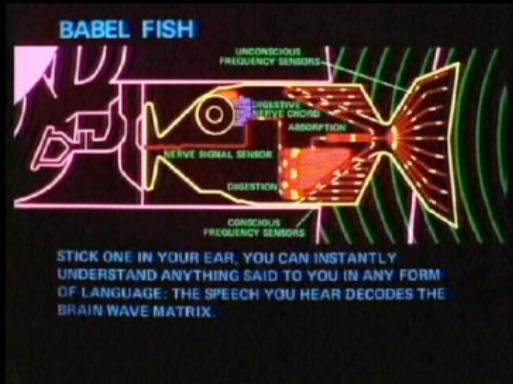
Gloria Ruth Gordon and Ester Gerson, first programmers



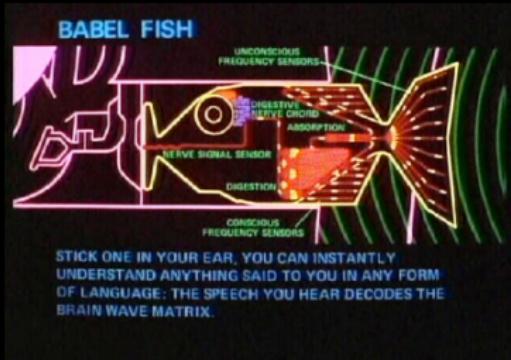
When I look at an article in Russian, I say: "This is really written in English, but it has been coded in some strange symbols. I will now proceed to decode."

Warren Weaver (1949)

Popular view of MT in 2005

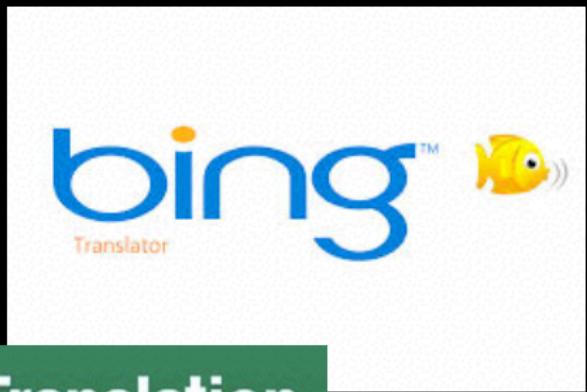


Popular view of MT in 2005



Popular view of NLP:

Popular view of MT in 2017



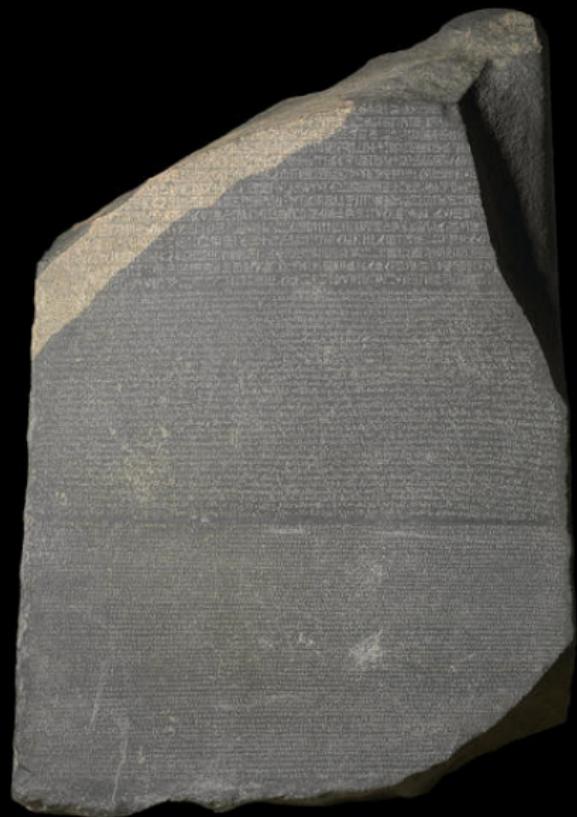
SDL freeTranslation

Popular view of MT in 2017

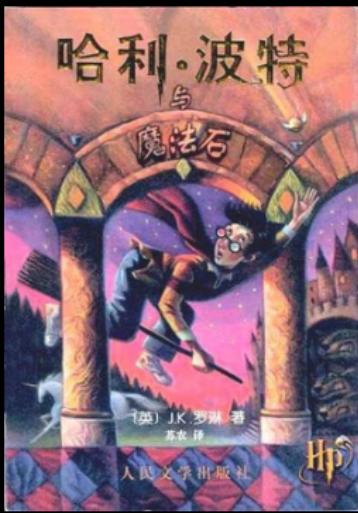
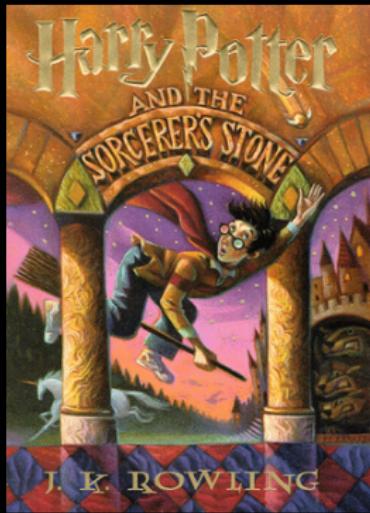


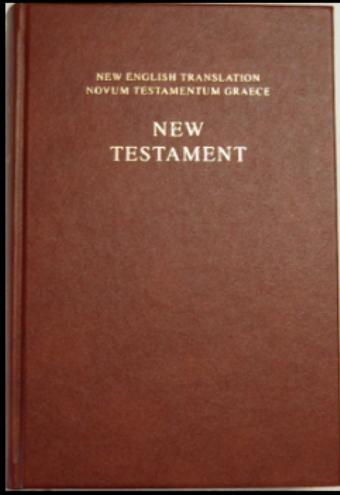
and NLP:











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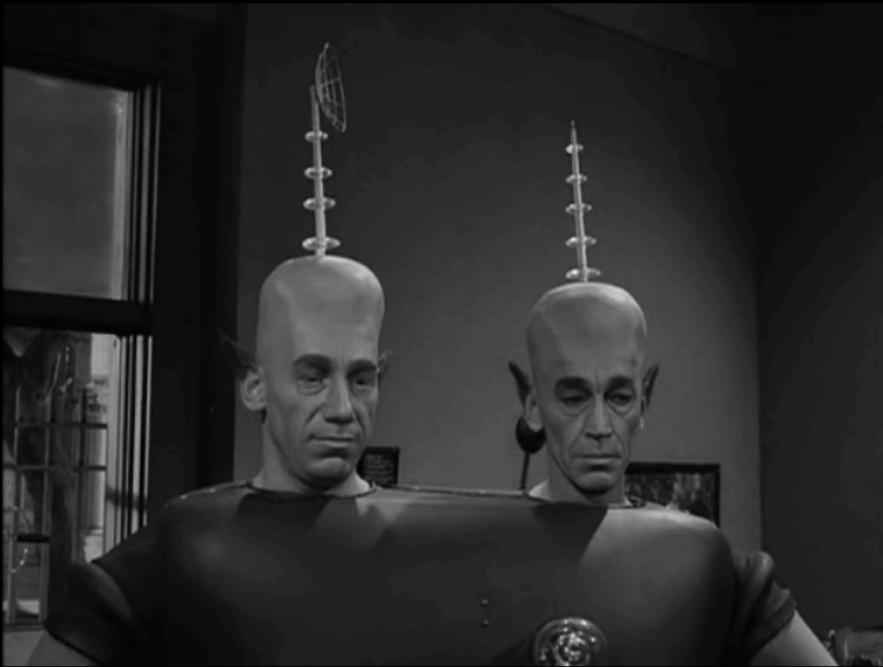
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联合国宗旨与原则

Translation Exercise



iat lat pippat eneat hilat oloat at-yurp .

ok-voon ororok sprok .

at-voon bichat dat .

ok-drubel ok-voon anok plok sprok .

at-drubel at-voon pippat rrat dat .
erok sprok izok hihok ghirok .

totat dat arrat vat hilat .

ok-voon anok drok brok jok .

at-voon krat pippat sat lat .

wiwok farok izok stok .

totat jjat quat cat .

lalok sprok izok jok stok .

wat dat krat quat cat .

lalok farok ororok lalok sprok izok enemok .

wat jjat bichat wat dat vat eneat .

lalok brok anok plok nok .

iat lat pippat rrat nnat .
wiwok nok izok kantok ok-yurp .

totat nnat quat oloat at-yurp .

lalok mok nok yorok ghirok clok .

wat nnat gat mat bat hilat .

lalok nok crrrok hihok yorok zanzanok .

wat nnat arrat mat zanzanat .

lalok rarok nok izok hihok mok .

wat nnat forat arrat vat gat .

iat lat pippat eneat hilat oloat at-yurp .

ok-voon ororok sprok .

at-voon bichat dat .

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at-voon krat pippat sat lat .

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wat dat krat quat cat .

lalok farok ororok lalok sprok izok enemok .

wat jjat bichat wat dat vat eneat .

lalok brok anok plok nok .

iat lat pippat rrat nnat .

wiwok nok izok kantok ok-yurp .

totat nnat quat oloat at-yurp .

lalok mok nok yorok ghirok clok .

wat nnat gat mat bat hilat .

lalok nok crrrok hihok yorok zanzanok .

wat nnat arrat mat zanzanat .

lalok rarok nok izok hihok mok .

wat nnat forat arrat vat gat .

iat lat pippat eneat hilat oloat at-yurp .

arrat : hihok	gat : mok	pippat : anok
at-drubel : ok-drubel	hilat : ghirok	quat : izok
at-voon : ok-voon	iat : lalok	rrat : plok
at-yurp : ok-yurp	jjat : farok	sat : drok
bat : clok	krat : jok	totat : erok
bichat : ororok	lat : brok	totat : wiwok
cat : stok	mat : yorok	vat : izok
dat : sprok	nnat : nok	wat : lalok
eneat : enemok	oloat : kantok	zanzanat : zanzanok
forat : rarok		??? : crrrok

iat lat pippat eneat hilat oloat at-yurp .

arrat : hihok	gat : mok	pippat : anok
at-drubel : ok-drubel	hilat : ghirok	quat : izok
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dat : sprok	nnat : nok	wat : lalok
eneat : enemok	oloat : kantok	zanzanat : zanzanok
forat : rarok		??? : crrrok

iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok enemok ghirok kantok ok-yurp .

arrat : hihok	gat : mok	pippat : anok
at-drubel : ok-drubel	hilat : ghirok	quat : izok
at-voon : ok-voon	iat : lalok	rrat : plok
at-yurp : ok-yurp	jjat : farok	sat : drok
bat : clok	krat : jok	totat : erok
bichat : ororok	lat : brok	totat : wiwok
cat : stok	mat : yorok	vat : izok
dat : sprok	nnat : nok	wat : lalok
eneat : enemok	oloat : kantok	zanzanat : zanzanok
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iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok enemok ghirok kantok ok-yurp .

erok sprok izok hihok ghirok .
totat dat arrat vat hilat .

ok-voon anok drok brok jok .
at-voon krat pippat sat lat .

lalok mok nok yorok ghirok clok .
wat nnat gat mat bat hilat .

lalok sprok izok jok stok .
wat dat krat quat cat .

lalok rarok nok izok hihok mok .
wat nnat forat arrat vat gat .

iat lat pippat eneat hilat oloat at-yurp .
lalok anok brok enemok kantok ghirok ok-yurp .

erok sprok izok hihok ghirok .
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wat nnat gat mat bat hilat .

lalok rarok nok izok hihok mok .
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iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok kantok ghirok enemok ok-yurp .

erok sprok izok hihok ghirok .
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at-voon krat pippat sat lat .

lalok mok nok yorok ghirok clok .
wat nnat gat mat bat hilat .

lalok sprok izok jok stok .
wat dat krat quat cat .

lalok rarok nok izok hihok mok .
wat nnat forat arrat vat gat .

iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok kantok ghirok enemok ok-yurp .

5040 possible orderings!

erok sprok izok hihok ghirok .
totat dat arrat vat hilat .

ok-voon anok drok brok jok .
at-voon krat pippat sat lat .

lalok mok nok yorok ghirok clok .
wat nnat gat mat bat hilat .

lalok sprok izok jok stok .
wat dat krat quat cat .

lalok rarok nok izok hihok mok .
wat nnat forat arrat vat gat .

iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok nemok ghirok kantok ok-yurp .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok ghirok nemok .
ok-drubel ziplok stok vok erok nemok kantok ok-yurp zinok jok yorok clok .
lalok clok izok vok ok-drubel .
ok-voon ororok sprok .
ok-drubel ok-voon anok plok sprok .
erok sprok izok hihok ghirok .
ok-voon anok drok brok jok .
wiwok farok izok stok .
lalok sprok izok jok stok .
lalok brok anok plok nok .
lalok farok ororok lalok sprok izok nemok .
wiwok nok izok kantok ok-yurp .
lalok mok nok yorok ghirok clok .
lalok nok crrrok hihok yorok zanzanok .
lalok rarok nok izok hihok mok .

iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok nemok ghirok kantok ok-yurp .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok ghirok nemok .
ok-drubel ziplok stok vok erok nemok kantok ok-yurp zinok jok yorok clok .
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ok-drubel anok ghirok farok .
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lalok nok crrrok hihok yorok zanzanok .
lalok rarok nok izok hihok mok .

iat lat pippat eneat hilat oloat at-yurp .
lalok brok **anok nemok** ghirok kantok ok-yurp .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok ghirok nemok .
ok-drubel ziplok stok vok erok nemok kantok ok-yurp zinok jok yorok clok .
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lalok brok anok **enemok ghirok** kantok ok-yurp .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok ghirok enemok .
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ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .
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lalok rarok nok izok hihok mok .

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lalok brok anok **ghirok enemok** kantok ok-yurp .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok **ghirok enemok** .
ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .
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lalok rarok nok izok hihok mok .

iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok ghirok enemok kantok ok-yurp .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok ghirok enemok .
ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .
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lalok nok crrrok hihok yorok zanzanok .
lalok rarok nok izok hihok mok .

iat lat pippat eneat hilat oloat at-yurp .
lalok brok **anok ghirok** enemok kantok ok-yurp .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok ghirok enemok .
ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .
lalok clok izok vok ok-drubel .
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ok-voon anok drok brok jok .
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lalok sprok izok jok stok .
lalok brok anok plok nok .
lalok farok ororok lalok sprok izok enemok .
wiwok nok izok kantok ok-yurp .
lalok mok nok yorok ghirok clok .
lalok nok crrrok hihok yorok zanzanok .
lalok rarok nok izok hihok mok .

iat lat pippat eneat hilat oloat at-yurp .
lalok brok **anok ghirok** enemok kantok ok-yurp .

ok-drubel **anok ghirok** farok .
wiwok rarok nok zerok ghirok enemok .
ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .
lalok clok izok vok ok-drubel .
ok-voon ororok sprok .
ok-drubel ok-voon anok plok sprok .
erok sprok izok hihok ghirok .
ok-voon anok drok brok jok .
wiwok farok izok stok .
lalok sprok izok jok stok .
lalok brok anok plok nok .
lalok farok ororok lalok sprok izok enemok .
wiwok nok izok kantok ok-yurp .
lalok mok nok yorok ghirok clok .
lalok nok crrrok hihok yorok zanzanok .
lalok rarok nok izok hihok mok .

iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok ghirok enemok kantok ok-yurp .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok ghirok enemok .
ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .
lalok clok izok vok ok-drubel .
ok-voon ororok sprok .
ok-drubel ok-voon anok plok sprok .
erok sprok izok hihok ghirok .
ok-voon anok drok brok jok .
wiwok farok izok stok .
lalok sprok izok jok stok .
lalok brok anok plok nok .
lalok farok ororok lalok sprok izok enemok .
wiwok nok izok kantok ok-yurp .
lalok mok nok yorok ghirok clok .
lalok nok crrrok hihok yorok zanzanok .
lalok rarok nok izok hihok mok .

iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok ghirok **enemok kantok** ok-yurp .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok ghirok enemok .
ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .
lalok clok izok vok ok-drubel .
ok-voon ororok sprok .
ok-drubel ok-voon anok plok sprok .
erok sprok izok hihok ghirok .
ok-voon anok drok brok jok .
wiwok farok izok stok .
lalok sprok izok jok stok .
lalok brok anok plok nok .
lalok farok ororok lalok sprok izok enemok .
wiwok nok izok kantok ok-yurp .
lalok mok nok yorok ghirok clok .
lalok nok crrrok hihok yorok zanzanok .
lalok rarok nok izok hihok mok .

iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok ghirok **enemok kantok** ok-yurp .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok ghirok enemok .
ok-drubel ziplok stok vok erok **enemok kantok** ok-yurp zinok jok yorok clok .
lalok clok izok vok ok-drubel .
ok-voon ororok sprok .
ok-drubel ok-voon anok plok sprok .
erok sprok izok hihok ghirok .
ok-voon anok drok brok jok .
wiwok farok izok stok .
lalok sprok izok jok stok .
lalok brok anok plok nok .
lalok farok ororok lalok sprok izok enemok .
wiwok nok izok kantok ok-yurp .
lalok mok nok yorok ghirok clok .
lalok nok crrrok hihok yorok zanzanok .
lalok rarok nok izok hihok mok .

iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok ghirok **enemok kantok ok-yurp** .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok ghirok enemok .
ok-drubel ziplok stok vok erok **enemok kantok ok-yurp** zinok jok yorok clok .
lalok clok izok vok ok-drubel .
ok-voon ororok sprok .
ok-drubel ok-voon anok plok sprok .
erok sprok izok hihok ghirok .
ok-voon anok drok brok jok .
wiwok farok izok stok .
lalok sprok izok jok stok .
lalok brok anok plok nok .
lalok farok ororok lalok sprok izok enemok .
wiwok nok izok kantok ok-yurp .
lalok mok nok yorok ghirok clok .
lalok nok crrrok hihok yorok zanzanok .
lalok rarok nok izok hihok mok .

totat nnat forat arrat mat bat .

totat nnat forat arrat mat bat .

arrat : hihok	gat : mok	pippat : anok
at-drubel : ok-drubel	hilat : ghirok	quat : izok
at-voon : ok-voon	iat : lalok	rrat : plok
at-yurp : ok-yurp	jjat : farok	sat : drok
bat : clok	krat : jok	totat : erok
bichat : ororok	lat : brok	totat : wiwok
cat : stok	mat : yorok	vat : izok
dat : sprok	nnat : nok	wat : lalok
eneat : enemok	oloat : kantok	zanzanat : zanzanok
forat : rarok		??? : crrrok

totat nnat forat arrat mat bat .

arrat : hihok

at-drubel : ok-drubel

at-voon : ok-voon

at-yurp : ok-yurp

bat : clok

bichat : ororok

cat : stok

dat : sprok

eneat : enemok

forat : rarok

gat : mok

hilat : ghirok

iat : lalok

jjat : farok

krat : jok

lat : brok

mat : yorok

nnat : nok

oloat : kantok

pippat : anok

quat : izok

rrat : plok

sat : drok

totat : erok

totat : wiwok

vat : izok

wat : lalok

zanzanat : zanzanok

??? : crrrok

totat nnat forat arrat mat bat .
erok | wiwok nok rarok hihok yorok clok .

arrat : hihok	gat : mok	pippat : anok
at-drubel : ok-drubel	hilat : ghirok	quat : izok
at-voon : ok-voon	iat : lalok	rrat : plok
at-yurp : ok-yurp	jjat : farok	sat : drok
bat : clok	krat : jok	totat : erok
bichat : ororok	lat : brok	totat : wiwok
cat : stok	mat : yorok	vat : izok
dat : sprok	nnat : nok	wat : lalok
eneat : enemok	oloat : kantok	zanzanat : zanzanok
forat : rarok		??? : crrrok

totat nnat forat arrat mat bat .
erok | wiwok nok rarok hihok yorok clok .

ok-drubel anok ghirok farok .

wiwok rarok nok zerok ghirok enemok .

ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .

lalok clok izok vok ok-drubel .

ok-voon ororok sprok .

ok-drubel ok-voon anok plok sprok .

erok sprok izok hihok ghirok .

ok-voon anok drok brok jok .

wiwok farok izok stok .

lalok sprok izok jok stok .

lalok brok anok plok nok .

lalok farok ororok lalok sprok izok enemok .

wiwok nok izok kantok ok-yurp .

lalok mok nok yorok ghirok clok .

lalok nok crrrok hihok yorok zanzanok .

lalok rarok nok izok hihok mok .

totat nnat forat arrat mat bat .
erok | **wiwok nok** rarok hihok yorok clok .

ok-drubel anok ghirok farok .

wiwok rarok nok zerok ghirok enemok .

ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .

lalok clok izok vok ok-drubel .

ok-voon ororok sprok .

ok-drubel ok-voon anok plok sprok .

erok sprok izok hihok ghirok .

ok-voon anok drok brok jok .

wiwok farok izok stok .

lalok sprok izok jok stok .

lalok brok anok plok nok .

lalok farok ororok lalok sprok izok enemok .

wiwok nok izok kantok ok-yurp .

lalok mok nok yorok ghirok clok .

lalok nok crrrok hihok yorok zanzanok .

lalok rarok nok izok hihok mok .

totat nnat forat arrat mat bat .
wiwok nok rarok hihok yorok clok .

ok-drubel anok ghirok farok .

wiwok rarok nok zerok ghirok enemok .

ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .

lalok clok izok vok ok-drubel .

ok-voon ororok sprok .

ok-drubel ok-voon anok plok sprok .

erok sprok izok hihok ghirok .

ok-voon anok drok brok jok .

wiwok farok izok stok .

lalok sprok izok jok stok .

lalok brok anok plok nok .

lalok farok ororok lalok sprok izok enemok .

wiwok nok izok kantok ok-yurp .

lalok mok nok yorok ghirok clok .

lalok nok crrrok hihok yorok zanzanok .

lalok rarok nok izok hihok mok .

totat nnat forat arrat mat bat .

wiwok rarok nok hihok yorok clok .

ok-drubel anok ghirok farok .

wiwok rarok nok zerok ghirok enemok .

ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .

lalok clok izok vok ok-drubel .

ok-voon ororok sprok .

ok-drubel ok-voon anok plok sprok .

erok sprok izok hihok ghirok .

ok-voon anok drok brok jok .

wiwok farok izok stok .

lalok sprok izok jok stok .

lalok brok anok plok nok .

lalok farok ororok lalok sprok izok enemok .

wiwok nok izok kantok ok-yurp .

lalok mok nok yorok ghirok clok .

lalok nok crrrok hihok yorok zanzanok .

lalok rarok nok izok hihok mok .

totat nnat forat arrat mat bat .

wiwok rarok nok hihok yorok clok .

ok-drubel anok ghirok farok .

wiwok rarok nok zerok ghirok nemok .

ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .

lalok clok izok vok ok-drubel .

ok-voon ororok sprok .

ok-drubel ok-voon anok plok sprok .

erok sprok izok hihok ghirok .

ok-voon anok drok brok jok .

wiwok farok izok stok .

lalok sprok izok jok stok .

lalok brok anok plok nok .

lalok farok ororok lalok sprok izok nemok .

wiwok nok izok kantok ok-yurp .

lalok mok nok yorok ghirok clok .

lalok nok crrrok hihok yorok zanzanok .

lalok rarok nok izok hihok mok .

totat nnat forat arrat mat bat .
wiwok rarok **nok hihok** yorok clok .

ok-drubel anok ghirok farok .

wiwok rarok nok zerok ghirok nemok .

ok-drubel ziplok stok vok erok nemok kantok ok-yurp zinok jok yorok clok .

lalok clok izok vok ok-drubel .

ok-voon ororok sprok .

ok-drubel ok-voon anok plok sprok .

erok sprok izok hihok ghirok .

ok-voon anok drok brok jok .

wiwok farok izok stok .

lalok sprok izok jok stok .

lalok brok anok plok nok .

lalok farok ororok lalok sprok izok nemok .

wiwok nok izok kantok ok-yurp .

lalok mok nok yorok ghirok clok .

lalok nok crrrok hihok yorok zanzanok .

lalok rarok nok izok hihok mok .

totat nnat forat arrat mat bat .
wiwok rarok **nok hihok** yorok clok .

ok-drubel anok ghirok farok .

wiwok rarok nok zerok ghirok nemok .

ok-drubel ziplok stok vok erok nemok kantok ok-yurp zinok jok yorok clok .

lalok clok izok vok ok-drubel .

ok-voon ororok sprok .

ok-drubel ok-voon anok plok sprok .

erok sprok izok hihok ghirok .

ok-voon anok drok brok jok .

wiwok farok izok stok .

lalok sprok izok jok stok .

lalok brok anok plok nok .

lalok farok ororok lalok sprok izok nemok .

wiwok nok izok kantok ok-yurp .

lalok mok nok yorok ghirok clok .

lalok **nok crrrok hihok yorok** zanzanok .

lalok rarok nok izok hihok mok .

totat nnat forat arrat mat bat .
wiwok rarok **nok crrrok hihok yorok** clok .

ok-drubel anok ghirok farok .

wiwok rarok nok zerok ghirok enemok .

ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .

lalok clok izok vok ok-drubel .

ok-voon ororok sprok .

ok-drubel ok-voon anok plok sprok .

erok sprok izok hihok ghirok .

ok-voon anok drok brok jok .

wiwok farok izok stok .

lalok sprok izok jok stok .

lalok brok anok plok nok .

lalok farok ororok lalok sprok izok enemok .

wiwok nok izok kantok ok-yurp .

lalok mok nok yorok ghirok clok .

lalok **nok crrrok hihok yorok** zanzanok .

lalok rarok nok izok hihok mok .

totat nnat forat arrat mat bat .
wiwok rarok nok crrrok hihok yorok clok .

ok-drubel anok ghirok farok .

wiwok rarok nok zerok ghirok enemok .

ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .

lalok clok izok vok ok-drubel .

ok-voon ororok sprok .

ok-drubel ok-voon anok plok sprok .

erok sprok izok hihok ghirok .

ok-voon anok drok brok jok .

wiwok farok izok stok .

lalok sprok izok jok stok .

lalok brok anok plok nok .

lalok farok ororok lalok sprok izok enemok .

wiwok nok izok kantok ok-yurp .

lalok mok nok yorok ghirok clok .

lalok nok crrrok hihok yorok zanzanok .

lalok rarok nok izok hihok mok .

totat nnat forat arrat mat bat .
wiwok rarok nok crrrok hihok **yorok clok** .

ok-drubel anok ghirok farok .
wiwok rarok nok zerok ghirok enemok .
ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok **yorok clok** .
lalok clok izok vok ok-drubel .
ok-voon ororok sprok .
ok-drubel ok-voon anok plok sprok .
erok sprok izok hihok ghirok .
ok-voon anok drok brok jok .
wiwok farok izok stok .
lalok sprok izok jok stok .
lalok brok anok plok nok .
lalok farok ororok lalok sprok izok enemok .
wiwok nok izok kantok ok-yurp .
lalok mok nok yorok ghirok clok .
lalok nok crrrok hihok yorok zanzanok .
lalok rarok nok izok hihok mok .

totat nnat forat arrat mat bat .
wiwok rarok nok crrrok hihok yorok clok .

ok-drubel anok ghirok farok .

wiwok rarok nok zerok ghirok enemok .

ok-drubel ziplok stok vok erok enemok kantok ok-yurp zinok jok yorok clok .

lalok clok izok vok ok-drubel .

ok-voon ororok sprok .

ok-drubel ok-voon anok plok sprok .

erok sprok izok hihok ghirok .

ok-voon anok drok brok jok .

wiwok farok izok stok .

lalok sprok izok jok stok .

lalok brok anok plok nok .

lalok farok ororok lalok sprok izok enemok .

wiwok nok izok kantok ok-yurp .

lalok mok nok yorok ghirok clok .

lalok nok crrrok hihok yorok zanzanok .

lalok rarok nok izok hihok mok .

Is this exercise realistic?

In real natural language...

Is this exercise realistic?

In real natural language...

...words are ambiguous

English: bank

French: banque



French: rive



Is this exercise realistic?

In real natural language...

...words have complex *morphology*

	singular	plural
nominative	I	we
oblique	me	us
possessive determiner	my	our
possessive pronoun	mine	ours
reflexive	myself	ourselves

Tense	I	you	he, she, it	we	you	they
Present	arrive	arrive	arrives	arrive	arrive	arrive
Past	arrived	arrived	arrived	arrived	arrived	arrived

Is this exercise realistic?

In real natural language...

...words have complex *morphology*

... fanden sie sie auf den Stufen unseres Hauses sitzend ...

... they found her sitting on the steps of our house ...

	Singular	Plural
Nominativ	das Haus	die Häuser
Genitiv	des Hauses	der Häuser
Dativ	dem Haus dem Hause	den Häusern
Akkusativ	das Haus	die Häuser

Is this exercise realistic?

forms of kataba ('to write') in Arabic

		Past	Present Indicative	Future Indicative	Subjunctive	Jussive	Long Energetic	Short Energetic	Imperative	
Active	1st	katab-t(u)	a-ktub-(u)	sa-a-ktub-(u)	a-ktub-(a)	a-ktub	a-ktub-an-na	a-ktub-an	-	
		كَتَبَ	أَكَتَبَ	سَأَكْتُبُ	أَكَتَبَ	أَكَتَبَ	أَكْتُبَانَا	أَكْتُبَ	-	
	2nd	masculine	katab-t(a)	ta-ktub-(u)	sa-ya-ktub-(u)	ta-ktub-(a)	ta-ktub	ta-ktub-an-na	ta-ktub-an	
			كَاتَبَ	تَكَتُبَ	سَأَيَّكْتُبُ	تَكَتُبَ	تَكَتُبَ	تَكْتُبَانَا	تَكْتُبَ	
	3rd	feminine	katab-ti	ta-ktub-in(a)	sa-ya-ktub-in(a)	ta-ktub-i	ta-ktub-i	ta-ktub-in-na	ta-ktub-in	
			كَاتَبَتِ	تَكَتُبَتِ	سَأَيَّكْتُبَتِ	تَكَتُبَتِ	تَكَتُبَتِ	تَكْتُبَتِانَا	تَكْتُبَتِ	
	2nd	masculine & feminine	katab-tumā	ta-ktub-ān(i)	sa-ya-ktub-ān(i)	ta-ktub-ā	ta-ktub-ā	ta-ktub-ānni	-	
			كَاتَبَتُمْ	تَكَتُبَتُمْ	سَأَيَّكْتُبَتُمْ	تَكَتُبَتُمْ	تَكَتُبَتُمْ	تَكْتُبَتُمْانِي	تَكْتُبَتُمْ	
	3rd	masculine	katab-ā	ya-ktub-an(i)	sa-ya-ktub-an(i)	ya-ktub-ā	ya-ktub-ā	ya-ktub-ānni	-	
			كَاتَبَهُ	يَكَتُبَهُ	سَأَيَّكْتُبَهُ	يَكَتُبَهُ	يَكَتُبَهُ	يَكْتُبَهُنِي	يَكْتُبَهُ	
	3rd	feminine	katab-ātā	ta-ktub-ān(i)	sa-ya-ktub-ān(i)	ta-ktub-ā	ta-ktub-ā	ta-ktub-ānni	-	
			كَاتَبَتَهَا	تَكَتُبَتَهَا	سَأَيَّكْتُبَتَهَا	تَكَتُبَتَهَا	تَكَتُبَتَهَا	تَكْتُبَتَهُنِي	تَكْتُبَتَهَا	
Passive	1st	kutub-t(u)	u-ktub-(u)	sa-u-ktub-(u)	u-ktub-(a)	u-ktub	u-ktub-an-na	u-ktub-an	-	
			كُتُبَتِ	سَأُكْتُبَ	أُكَتَبَ	أُكَتَبَ	أُكْتُبَانَا	أُكْتُبَ	-	
	2nd	masculine	kutub-t(a)	tu-ktub-(u)	sa-ya-ktub-(u)	tu-ktub-(a)	tu-ktub	tu-ktub-an-na	tu-ktub-an	
			كُتُبَتِ	تَكُتُبَ	سَأَيَّكْتُبَ	تَكُتُبَ	تَكُتُبَ	تَكْتُبَانَا	تَكْتُبَ	
	3rd	feminine	kutub-ti	tu-ktub-in(a)	sa-ya-ktub-in(a)	tu-ktub-i	tu-ktub-i	tu-ktub-in-na	tu-ktub-in	
			كُتُبَتِ	تَكُتُبَتِ	سَأَيَّكْتُبَتِ	تَكُتُبَتِ	تَكُتُبَتِ	تَكْتُبَتِانَا	تَكْتُبَتِ	
	2nd	masculine	kutub-ā	ya-ktub-(u)	sa-ya-ktub-(u)	ya-ktub-ā	ya-ktub-ā	ya-ktub-ānni	-	
			كُتُبَهُ	يَكَتُبَهُ	سَأَيَّكْتُبَهُ	يَكَتُبَهُ	يَكَتُبَهُ	يَكْتُبَهُنِي	يَكْتُبَهُ	
	3rd	feminine	kutub-ātā	tu-ktub-ān(i)	sa-ya-ktub-ān(i)	tu-ktub-ā	tu-ktub-ā	tu-ktub-ānni	-	
			كُتُبَهَا	تَكُتُبَهَا	سَأَيَّكْتُبَهَا	تَكُتُبَهَا	تَكُتُبَهَا	تَكْتُبَهُنِي	تَكْتُبَهَا	
	etc.									
Nominal	Active Participle				Passive Participle				Verbal Noun	
	katab				mabit				katab, kitabah, kitabah	
		كَاتِبٌ		مَبِيتٌ		مَبِيتٌ		مَبِيتٌ	كَاتِبٌ، كِتَابٌ، كِتَابَةٌ	

Is this exercise realistic?

In real natural language...

...words have complex *morphology*

Finnish: ostoskeskuksessa

ostos#keskus+N+Sg+Loc:in

shopping#center+N+Sg+Loc:in

English: ‘in the shopping center’

Is this exercise realistic?

In real natural language...

...words may have non-standard *orthography*

data why pluto is pluto it can neva b a star

Is this exercise realistic?

In real natural language...

...word order matters

Jaime loves Casey

Casey loves Jaime

Is this exercise realistic?

In real natural language...

...every word matters

12 ¶ * Honour thy father and thy mother,
thy dayes may bee long vpon the land whiche
LORD thy God giueth thee.

13 * Thou shalt not kill.

14 Thou shalt commit adultery.

15 Thou shalt not steale.

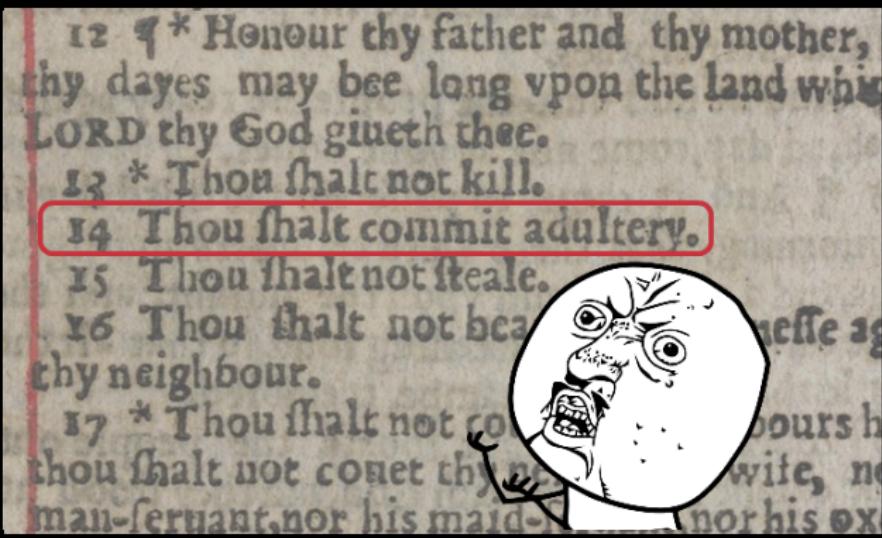
16 Thou shalt not beare false witness agynst
thy neighbour.

17 * Thou shalt not couet thy neighbours house,
thou shalt not couet thy neighbours wife, nor
man-servant,nor his maid-servant,nor his ox

Is this exercise realistic?

In real natural language...

...every word matters



Is this exercise realistic?

In real natural language...

...sentences are longer.

One of Scotland's leading cultural heritage groups will stage the Mary, Queen of Scots Festival, which is hoped to become a major new attraction for the area, which has lost the T in the Park music festival this summer after 18 years.

Is this exercise realistic?

iat lat pippat eneat hilat oloat at-yurp .
lalok brok anok ghirok enemok kantok ok-yurp .

ok-voon ororok sprok .

at-voon bichat dat .

ok-drubel ok-voon anok plok sprok .

at-drubel at-voon pippat rrat dat .

erok sprok izok hihok ghirok .

totat dat arrat vat hilat .

ok-voon anok drok brok jok .

at-voon krat pippat sat lat .

wiwok farok izok stok .

totat jjat quat cat .

lalok sprok izok jok stok .

wat dat krat quat cat .

lalok farok ororok lalok sprok izok enemok .

wat jjat bichat wat dat vat eneat .

lalok brok anok plok nok .

iat lat pippat rrat nnat .

wiwok nok izok kantok ok-yurp .

totat nnat quat oloat at-yurp .

lalok mok nok yorok ghirok clok .

wat nnat gat mat bat hilat .

lalok nok crrrok hihok yorok zanzanok .

wat nnat arrat mat zanzanat .

lalok rarok nok izok hihok mok .

wat nnat forat arrat vat gat .

la empresa tiene enemigos fuertes en Europa .

Garcia and associates .

\ \ /
Garcia y asociados .

Carlos Garcia has three associates .

\ | | | /
Carlos Garcia tiene tres asociados .

his associates are not strong .

| \ X /
sus asociados no son fuertes .

Garcia has a company also .

\ | X X X
Garcia tambien tiene una empresa .

its clients are angry .

/ / | \
sus clientes estan enfadados .

the associates are also angry .

/ / X \
los asociados tambien estan enfadados .

the clients and the associates are enemies .

\ \ | / | / / /
los clientes y los asociados son enemigos .

the company has three groups .

\ | | / / /
la empresa tiene tres grupos .

its groups are in Europe .

/ | | | \ /
sus grupos estan en Europa .

the modern groups sell strong pharmaceuticals .

| X X \ / X X
los grupos modernos venden medicinas fuertes .

the groups do not sell zanzanine .

/ | / / / /
los grupos no venden zanzania .

the small groups are not modern .

/ X X \ /
los grupos pequenos no son modernos .

la empresa tiene enemigos fuertes en Europa .
the company has strong enemies in Europe .

Garcia and associates .

\ \ /
Garcia y asociados .

Carlos Garcia has three associates .

\ | | | /
Carlos Garcia tiene tres asociados .

his associates are not strong .

| \ X /
sus asociados no son fuertes .

Garcia has a company also .

\ X X X
Garcia tambien tiene una empresa .

its clients are angry .

/ / | \
sus clientes estan enfadados .

the associates are also angry .

/ / X \
los asociados tambien estan enfadados .

the clients and the associates are enemies .

\ | | / | / / /
los clientes y los asociados son enemigos .

the company has three groups .

\ | | / | / /
la empresa tiene tres grupos .

its groups are in Europe .

/ | | | \ /
sus grupos estan en Europa .

the modern groups sell strong pharmaceuticals .

| X \ X /
los grupos modernos venden medicinas fuertes .

the groups do not sell zanzanine .

| | / | / /
los grupos no venden zanzania .

the small groups are not modern .

/ X X \
los grupos pequenos no son modernos .

Goals of this Course

at the end of this course, you will:

- understand the linguistic and computational challenges of MT
- know how MT is formalized as a machine learning problem
- have experience reading, using and modifying an MT implementation
- understand state-of-the-art approaches to MT and their limitations

our focus:

- sequence-to-sequence models with deep learning
→ applications beyond MT
- probabilistic models of language

“Probabilistic models of language”

This course is about implementing...

```
for ej, logprob, fi, fj in alignments[ei]:  
    if bitmap(range(fi,fj)) & v == 0:  
        new_v = bitmap(range(fi,fj)) | v  
        if new_v in chart[ej]:  
            chart[ej][new_v] = logadd10(chart[ej][new_v], sums[v]+logprob)  
        else:  
            chart[ej][new_v] = sums[v]+logprob
```

...probabilistic models...

$$\mathcal{L}(\theta|\mathcal{D}) = p_\theta(\mathcal{D}|\theta) = \prod_{n=1}^N p_\theta(\mathbf{f}^{(n)}, \mathbf{a}^{(n)}|\mathbf{e}^{(n)}) = \prod_{n=1}^N p(I^{(n)}|J^{(n)}) \prod_{i=1}^{I^{(n)}} p(a_i^{(n)}|J^{(n)}) \cdot p(f_i^{(n)}|e_{a_i}^{(n)})$$

...of language

Ngaragana-nguja ngiy-a gujinganjanga-ni jiyawu ngabulu
grog-PROP.IV.ACC 3.SG.NM.A-PST morther.II.ERG give milk.IV.ACC
`(His) mother gave (him) milk with grog in it.' [wmb]

“Probabilistic models of language”

Very few people are experts in computer science, mathematics, and linguistics, and I **guarantee** you will encounter something you don't know. But if you are unwilling to engage with all of these topics,

DO NOT TAKE THIS COURSE

“Probabilistic models of language”

To future students: There is no way that you should take this course. The reason why is that you need to be competent in linguistics, mathematics and Python programming to do well in the coursework. The lecturer neglected to mention that he expected people to have those skills, but it was clear from the assignments. You will get no help, as there are no tutorials, there is only a forum where you can ask questions, but when a student asked for help because they did not understand the material, the lecturer was not willing to make any changes.

- 2015 course review from someone who didn't listen to the advice on the previous slide.

“Probabilistic models of language”

The teaching team is willing to answer questions on piazza. You will get more out of this if you also answer questions.

If you want answers to questions you must be **specific**. This is not specific (nor is it a question):

Need more help

I would like to write on behalf of a group of people who are finding this assignment impossible.

Requirements

pre-requisites

It is RECOMMENDED that students have passed

- Advanced Natural Language Processing (INFR11059) OR
- Accelerated Natural Language Processing (INFR11125) OR
- Foundations of Natural Language Processing (INFR09028)

if you have no NLP background, you'll have a bad time

Requirements

other requirements

Students are expected to understand the following topics, or be prepared to learn them independently:

- Discrete mathematics: analysis of algorithms, dynamic programming, basic graph algorithms, finite and pushdown automata.
- Other essential maths: basic probability theory; basic calculus and linear algebra; ability to read and manipulate mathematical notation including sums, products, log, and exp.
- Programming: ability to read and modify python programs; ability to design and implement a function based on high-level description such as pseudocode or a precise mathematical statement of what the function computes.
- Linguistics: willingness to learn basic elements of linguistic description; no formal linguistics background required.

warning: you will need these skills to pass the coursework and exam

Still Interested?

course overview

- ≈ 15 lectures, Monday and Thursday 4-5pm
- course work, due in week 8 (March 15, 3pm) – 30% of final grade
- written exam – 70% of final grade

tasks until Thursday

- sign up for piazza
- review the course syllabus
- review Koehn, 13.2-3