

# GROUP 26:

## (FOUNDATION FOR NEAR-TERM QUANTUM NATURAL LANGUAGE PROCESSING)

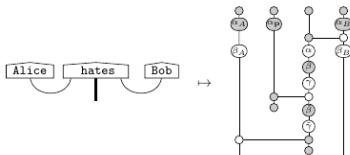
(BOB COECKE, GIOVANNI DE FELICE, KONSTANTINOS MEICHANETZIDIS, ALEXIS TOUMI)

MD. GALIB AHSAN

ID: 20166062

CSE-712

BRAC UNIVERSITY

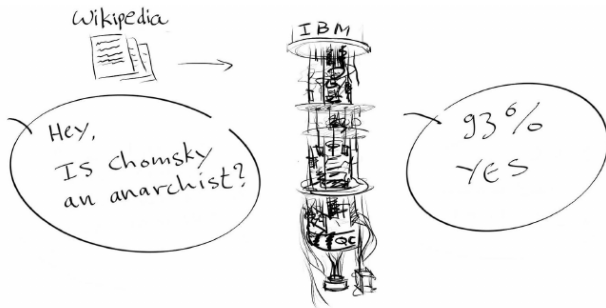


**WHERE TO LOOK:**

## WHERE TO LOOK:

- Canonically combines structure and meaning.
- Apparently exponentially expensive classical encoding of grammar to free lunch!
- Diagrammatic formalism of CQM.
- DisCoCat
- ZX-calculus
- Wittenstein's meaning-is-context.

# QUANTUM MODEL FOR NATURAL LANGUAGE



# APPLYING "ADJECTIVE" TO A "NOUN"

$$|\psi_{\text{a.n.}}\rangle = \eta_{\text{a}}(|\psi_{\text{n.}}\rangle)$$

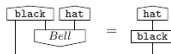
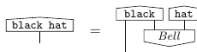
$$\boxed{\text{black hat}} = \boxed{\text{black}} \begin{array}{c} \boxed{\text{hat}} \\ | \end{array}$$

$$|\psi_{\text{a.n.}}\rangle \rightsquigarrow \boxed{\text{black hat}} \quad |\psi_{\text{n.}}\rangle \rightsquigarrow \boxed{\text{hat}} \quad \eta_{\text{a}} \rightsquigarrow \boxed{\text{black}}$$

# APPLYING "ADJECTIVE" TO A "NOUN"

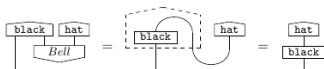
$$\eta_{00}|0\rangle\langle 0| + \eta_{01}|0\rangle\langle 1| + \eta_{10}|1\rangle\langle 0| + \eta_{11}|1\rangle\langle 1| \mapsto \eta_{00}|00\rangle + \eta_{01}|01\rangle + \eta_{10}|10\rangle + \eta_{11}|11\rangle$$

$$|\psi_{\mathbf{a},\mathbf{n}}\rangle = (\mathbb{I} \otimes \langle Bell|) \circ (|\psi_{\mathbf{a}}\rangle \otimes |\psi_{\mathbf{n}}\rangle)$$



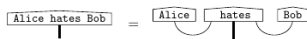
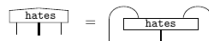
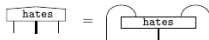
$$|Bell\rangle = \text{cup}$$

$$\langle Bell| = \text{cap}$$



# FEEDING A "SUBJECT" AND AN "OBJECT" INTO A "VERB":

$$|\psi_{n_s \text{tv} n_o}\rangle = \eta_{\text{tv}}(|\psi_{n_s}\rangle \otimes |\psi_{n_o}\rangle)$$



$$|\psi_{n_s \text{tv} n_o}\rangle = \left( \langle Bell | \otimes \mathbb{I} \otimes \langle Bell | \right) \circ \left( |\psi_{n_s}\rangle \otimes |\psi_{\text{tv}}\rangle \otimes |\psi_{n_o}\rangle \right)$$



# FUNCTIONAL WORDS SUCH AS RELATIVE PRONOUNS:

$$\text{Diagram: a circle with four dots (two on top, two on bottom) and two lines crossing at the center} = \sum_i |i \dots i\rangle \langle i \dots i|$$

$$\text{Diagram: a circle with two dots on top and one line entering from the bottom} = \sum_i |ii\rangle \langle i|$$

$$\text{Diagram: a circle with two dots on top and one line entering from the top} = \sum_i |i\rangle \langle ii|$$

$$\text{Diagram: a circle with one dot on top and one line entering from the top} = \sum_i \langle i|$$

$$\text{Diagram: a vertical line} = \sum_i |i\rangle \langle i|$$

$$\text{Diagram: a semi-circle (cap)} = \sum_i |ii\rangle$$

$$\text{Diagram: a semi-circle (cup)} = \sum_i \langle ii|$$

$$\text{Diagram: a complex diagram with multiple crossings and dots} = \text{Diagram: a crossing with four dots}$$

$$|\psi_{\text{who}}\rangle = \left(|00\rangle \left(\sum_i |i\rangle\right) |0\rangle\right) + \left(|11\rangle \left(\sum_j |j\rangle\right) |1\rangle\right)$$

$$|GHZ\rangle = |000\rangle + |111\rangle$$



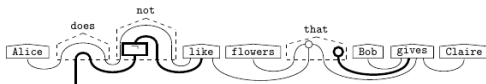
# FUNCTIONAL WORDS SUCH AS RELATIVE PRONOUNS:



$$|\psi_{\mathbf{n}_h \mathbf{r} \mathbf{p} \mathbf{t} \mathbf{v} \mathbf{n}_o}\rangle = \left( (|0\rangle\langle 00| + |1\rangle\langle 11|) \otimes \left( \sum_{j=1}^{j=k} |j\rangle \right) \otimes \langle Bell| \right) \circ \left( |\psi_{\mathbf{n}_h}\rangle \otimes |\psi_{\mathbf{t} \mathbf{v}}\rangle \otimes |\psi_{\mathbf{n}_o}\rangle \right)$$

# THE GENERAL CASE:

$$f_{\mathcal{G}}(|\psi_{w_1}\rangle \otimes \dots \otimes |\psi_{w_N}\rangle)$$



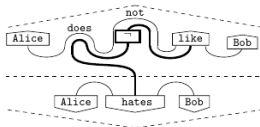
*Grammar is what mediates the flows of meanings between words.*

# COMPARING MEANINGS:

Alice hates Bob      and      Alice does not like Bob

$$|\psi_{w_1, \dots, w_N}\rangle \mapsto \langle \psi_{w_1, \dots, w_N}|$$

$$\langle \psi_{w_1, \dots, w_N} | \psi_{w'_1, \dots, w'_N} \rangle$$



# FREE LUNCH!!



If you think you understand  
quantum mechanics, you don't  
understand quantum mechanics.

— *Richard P. Feynman* —

AZ QUOTES