Title: From quantum picturalism to quantum NLP and quantum AI

Speakers: Bob Coecke

Series: Quantum Foundations

Date: August 25, 2023 - 2:00 PM

URL: https://pirsa.org/23080034

Abstract: In 2020 our Oxford-based Quantinuum team performed Quantum Natural Language Processing (QNLP) on IBM quantum hardware [1, 2]. Key to having been able to achieve what is conceived as a heavily data-driven task, is the observation that quantum theory and natural language are governed by much of the same compositional structure -- a.k.a. tensor structure.

Hence our language model is in a sense quantum-native, and we provide an analogy with simulation of quantum systems in terms of algorithmic speed-up [forthcoming]. Meanwhile we have made all our software available open-source, and with support [github.com/CQCL/lambeq].

The compositional match between natural language and quantum extends to other domains than language, and argue that a new generation of AI can emerge when fully pushing this analogy, while exploiting the completeness of categorical quantum mechanics / ZX-calculus [3, 4, 5] for novel reasoning purposes that go hand-in-hand with modern machine learning.

[1] B. Coecke, G. De Felice, K. Meichanetzidis and A. Toumi (2020) Foundations for Near-Term Quantum Natural Language Processing. https://arxiv.org/abs/2012.03755

[2] R. Lorenz, A. Pearson, K. Meichanetzidis, D. Kartsaklis and B. Coecke (2020) QNLP in Practice: Running Compositional Models of Meaning on a Quantum Computer. https://arxiv.org/abs/2102.12846

[3] B. Coecke and A. Kissinger (2017) Picturing Quantum Processes. A first course on quantum theory and diagrammatic reasoning. Cambridge University Press.

[4] B. Coecke, D. Horsman, A. Kissinger and Q. Wang (2021) Kindergarten quantum mechanics graduates (...or how I learned to stop gluing LEGO together and love the ZX-calculus). https://arxiv.org/abs/2102.10984

[5] B. Coecke and S. Gogioso (2022) Quantum in Pictures. Quantinuum, 2023.

Zoom Link: https://pitp.zoom.us/j/92333285960?pwd=MlpJSklmMlVlUlRTTWhsNjc2T2Y4QT09

From quantum picturalism to quantum NLP and quantum AI

Bob Coecke

Chief Scientist
Quantinuum

Emeritus Fellow
Wolfson College, Oxford

Distinguished Visiting Research Chair
Perimeter Institute for Theoretical Physics

2007-2020

Professor @ Oxford University

UNIVERSITY OF OXFORD

DEPARTMENT OF
COMPUTER SCIENCE

Professor Bob Coecke

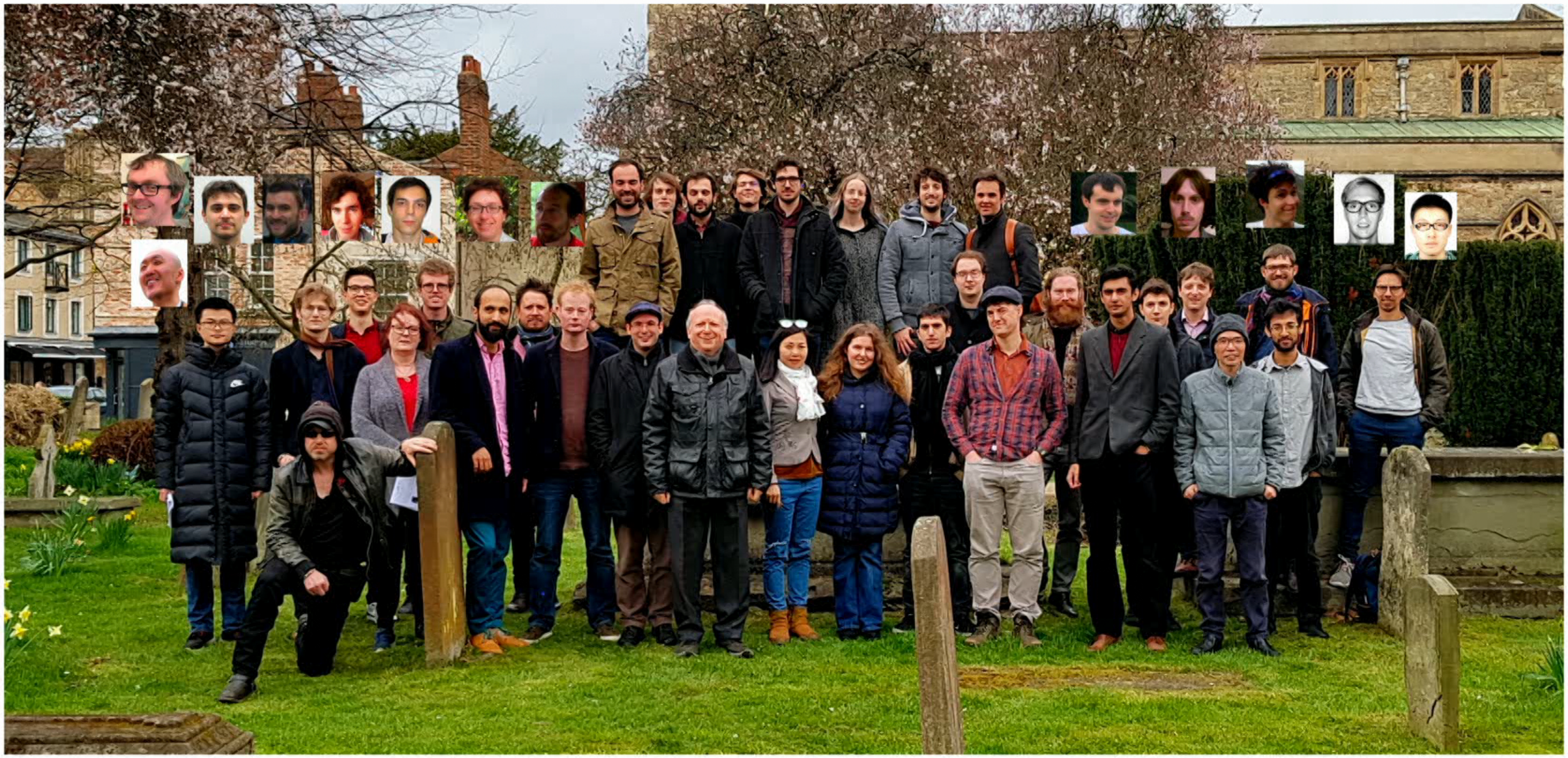
Professor of Quantum Foundations, Logics and Structures

Fellow, Wolfson College

Leaving date: 31st December 2020

2007-2020

Professor @ Oxford University



2020-2021

Chief Scientist @ Cambridge Quantum

BUSINESSWEEKLY

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NEWS TECH TRAIL TRADE FLOOR EXPORT THE KILLER 50 BLOGS BUSINESS AWA

6 January, 2021 - 10:54 By Tony Quested

Global guru named chief scientist of Cambridge Quantum Computing

World leading authority and Oxford don Bob Coecke has added yet another dimension to the non-stop progress of Cambridge Quantum Computing (CQC) by becoming chief scientist.

2021-2022

Chief Scientist @ Quantinuum

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Jun 8, 2021, 09:04am EDT | 49,374 views

Honeywell Quantum Solutions And Cambridge Quantum Computing Merge With Go-Public In Mind

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Analyst-in-residence, Quantum Computing

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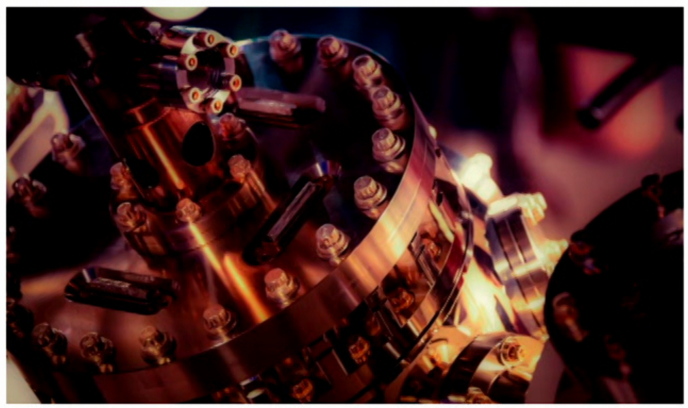
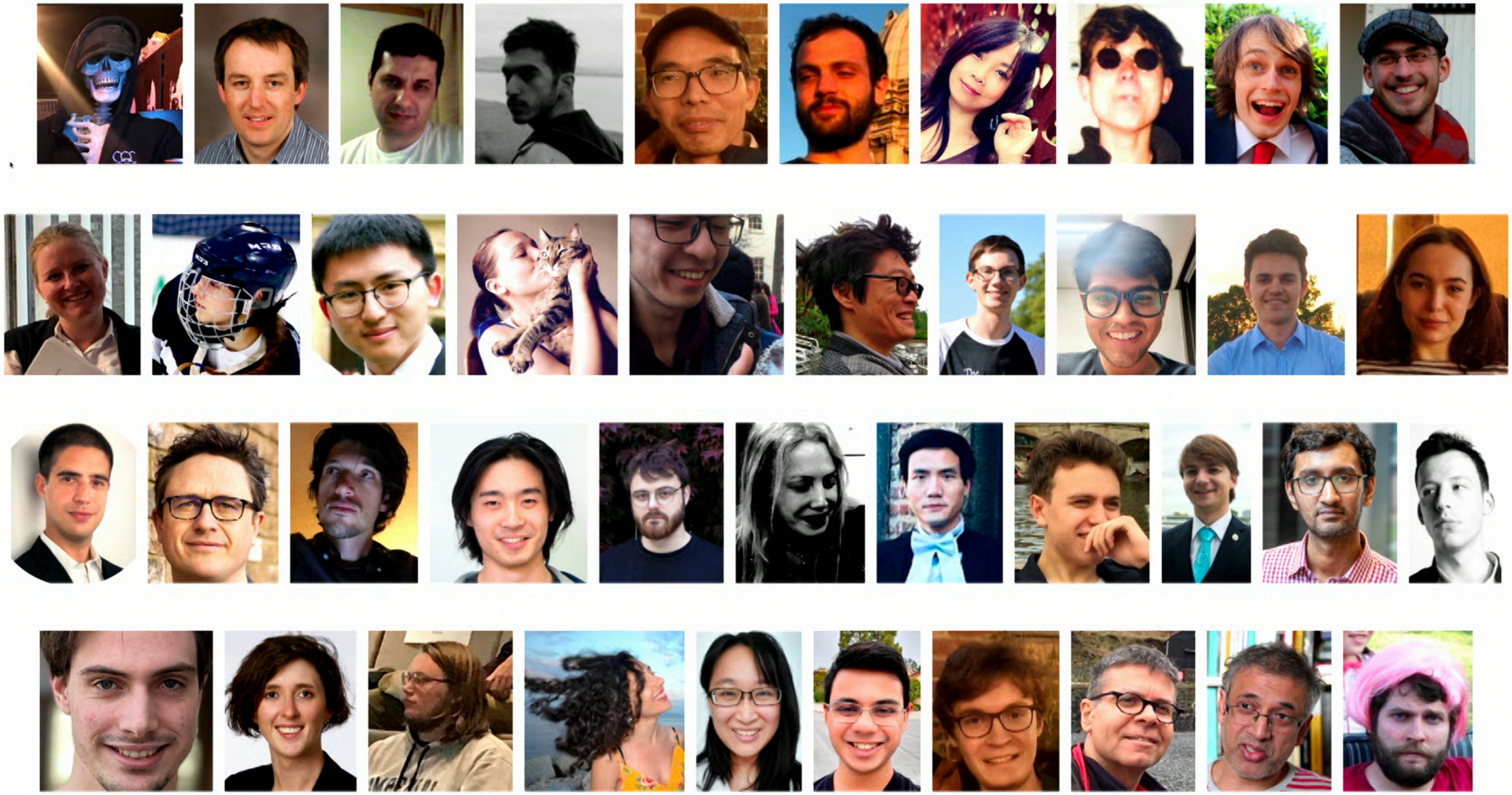


Quantinuum @ Oxford



our logo

John von Neumann

John von Neumann

I would like to make a confession which may seem immoral: I do not believe absolutely in Hilbert space any more. After all, Hilbert space (as far as quantum mechanical things are concerned) was obtained by generalizing Euclidean space, footing on the principle of 'conserving the validity of all formal rules' [. . .]. Now we begin to believe that it is not the *vectors* which matter, but the lattice of all linear (closed) subspaces. Because: 1) The vectors ought to represent the physical *states*, but they do it redundantly, up to a complex factor, only 2) and besides, the states are merely a derived notion, the primitive (phenomenologically given) notion being the qualities which correspond to the *linear closed subspaces* [von Neumann (1935) as quoted in Birkhoff (1966)]

Erwin Schrödinger

DISCUSSION OF PROBABILITY RELATIONS BETWEEN SEPARATED SYSTEMS

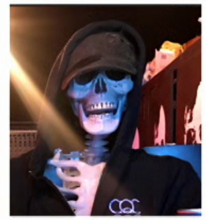
By E. SCHRÖDINGER

[Communicated by Mr M. Born]

[*Received* 14 August, *read* 28 October 1935]

1. When two systems, of which we know the states by their respective representatives, enter into temporary physical interaction due to known forces between them, and when after a time of mutual influence the systems separate again, then they can no longer be described in the same way as before, viz. by endowing each of them with a representative of its own. I would not call that *one* but rather *the* characteristic trait of quantum mechanics, the one that enforces its entire departure from classical lines of thought. By the interaction the two repre-

Schrödinger's view from monoidal category theory (2004)



arXiv.org > quant-ph > arXiv:quant-ph/0402130

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Quantum Physics

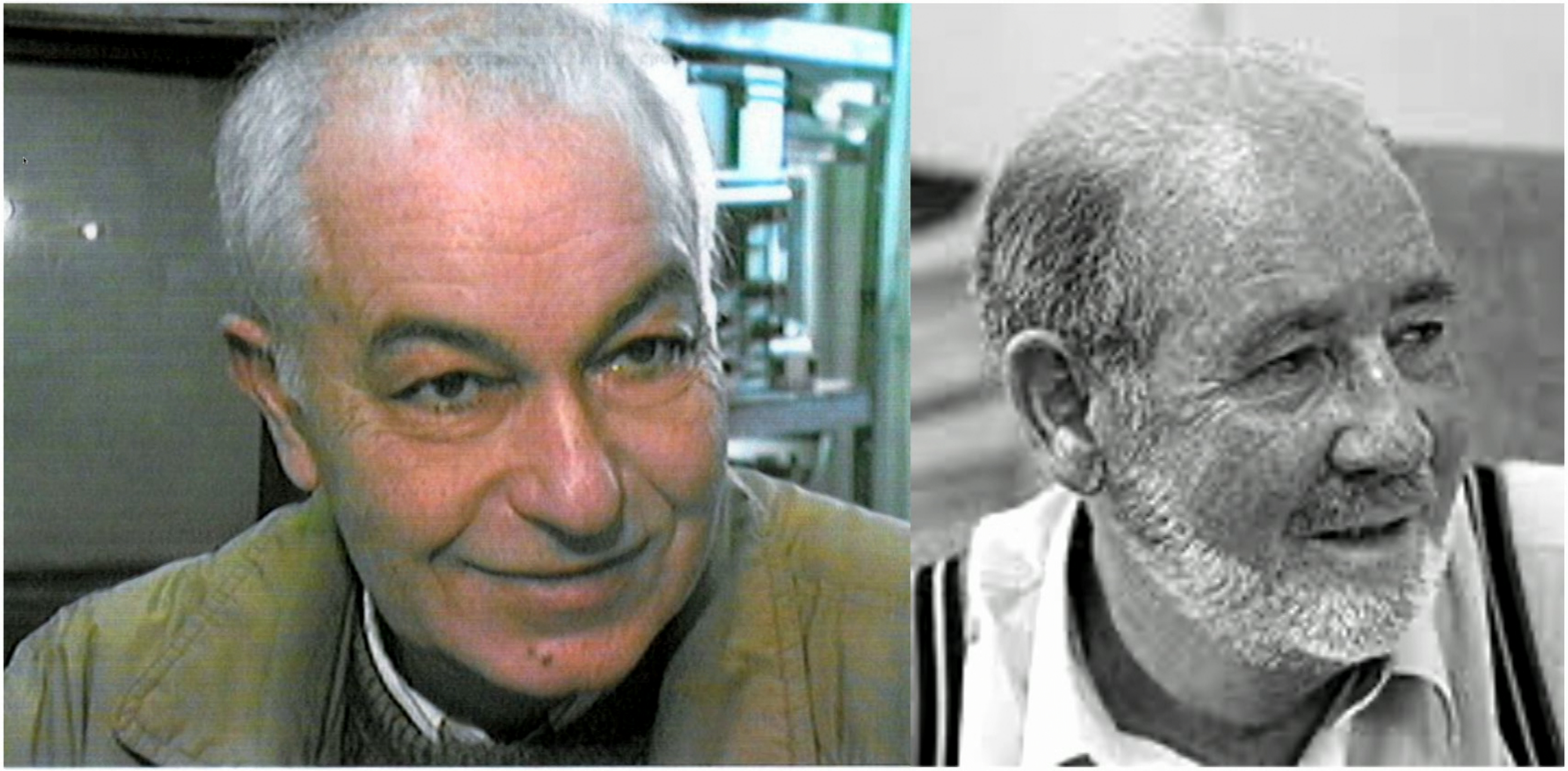
[Submitted on 18 Feb 2004 (v1), last revised 5 Mar 2007 (this version, v5)]

A categorical semantics of quantum protocols

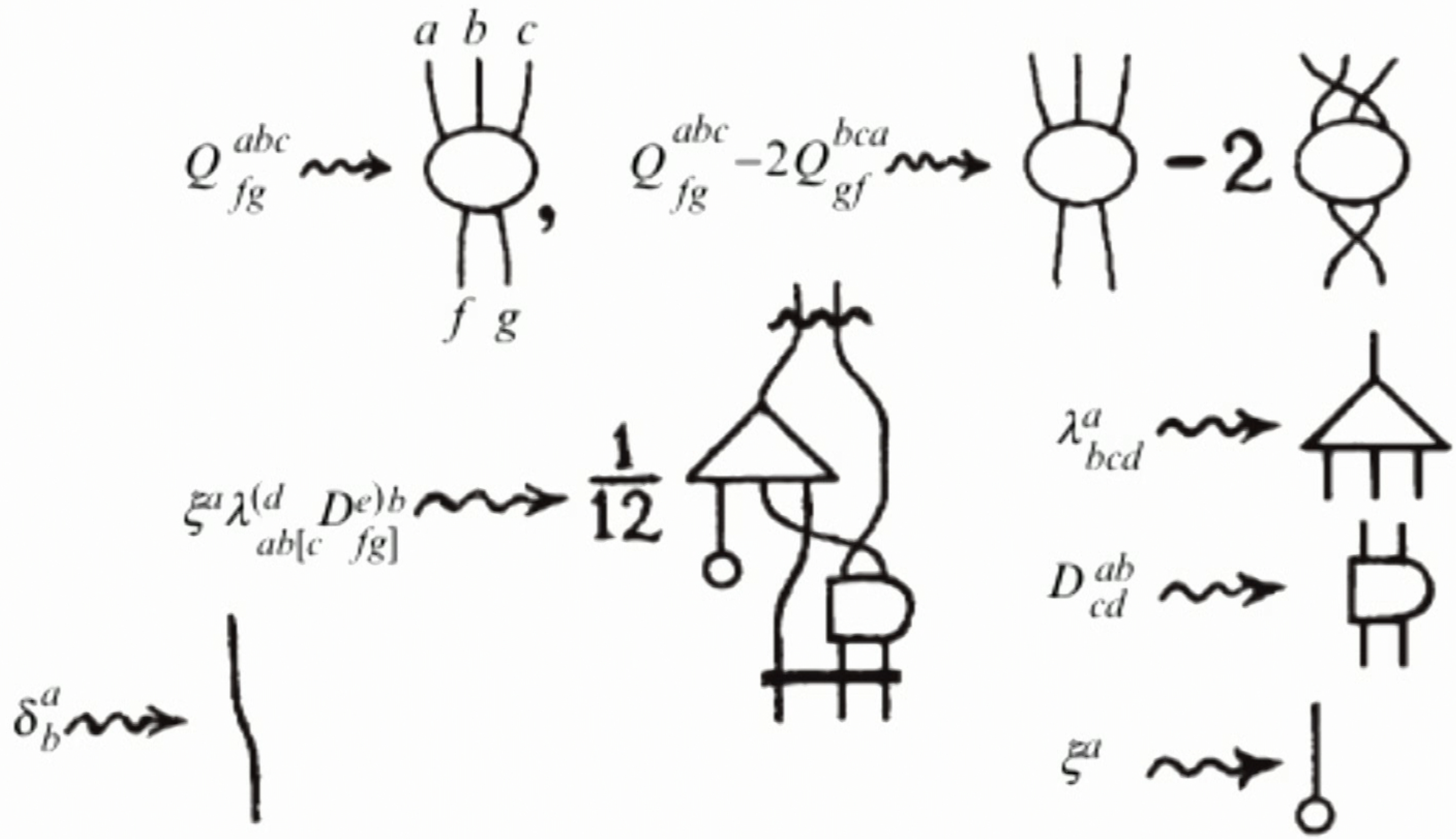
Samson Abramsky, Bob Coecke

We study quantum information and computation from a novel point of view. Our approach is based on recasting the standard axiomatic presentation of quantum mechanics, due to von Neumann, at a more abstract level, of compact closed categories with biproducts. We show how the essential structures found in key quantum information protocols such as teleportation, logic-gate teleportation, and entanglement-swapping can be captured at this abstract level. Moreover, from the combination of the -- apparently purely qualitative-- structures of compact closure and biproducts there emerge `scalars` and a `Born rule'. This abstract and structural point of view opens up new possibilities for describing and reasoning about quantum systems. It also shows the degrees of axiomatic freedom: we can show what requirements are placed on the (semi)ring of scalars C(I,I), where C is the category and I is the tensor unit, in order to perform various protocols such as teleportation. Our formalism captures both the information-flow aspect of the protocols (see quant-ph/0402014), and the branching due to quantum indeterminism. This contrasts with the standard accounts, in which the classical information flows are `outside' the usual quantum-mechanical formalism.

Jean Benabou & Max Kelly (& a dagger)

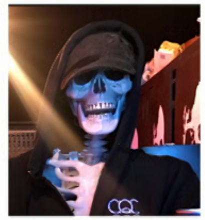


Roger Penrose



André Joyal & Ross Street

Schrödinger's view from Penrose's pictures, the plan (2005)



arXiv.org > quant-ph > arXiv:quant-ph/0510032

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Quantum Physics

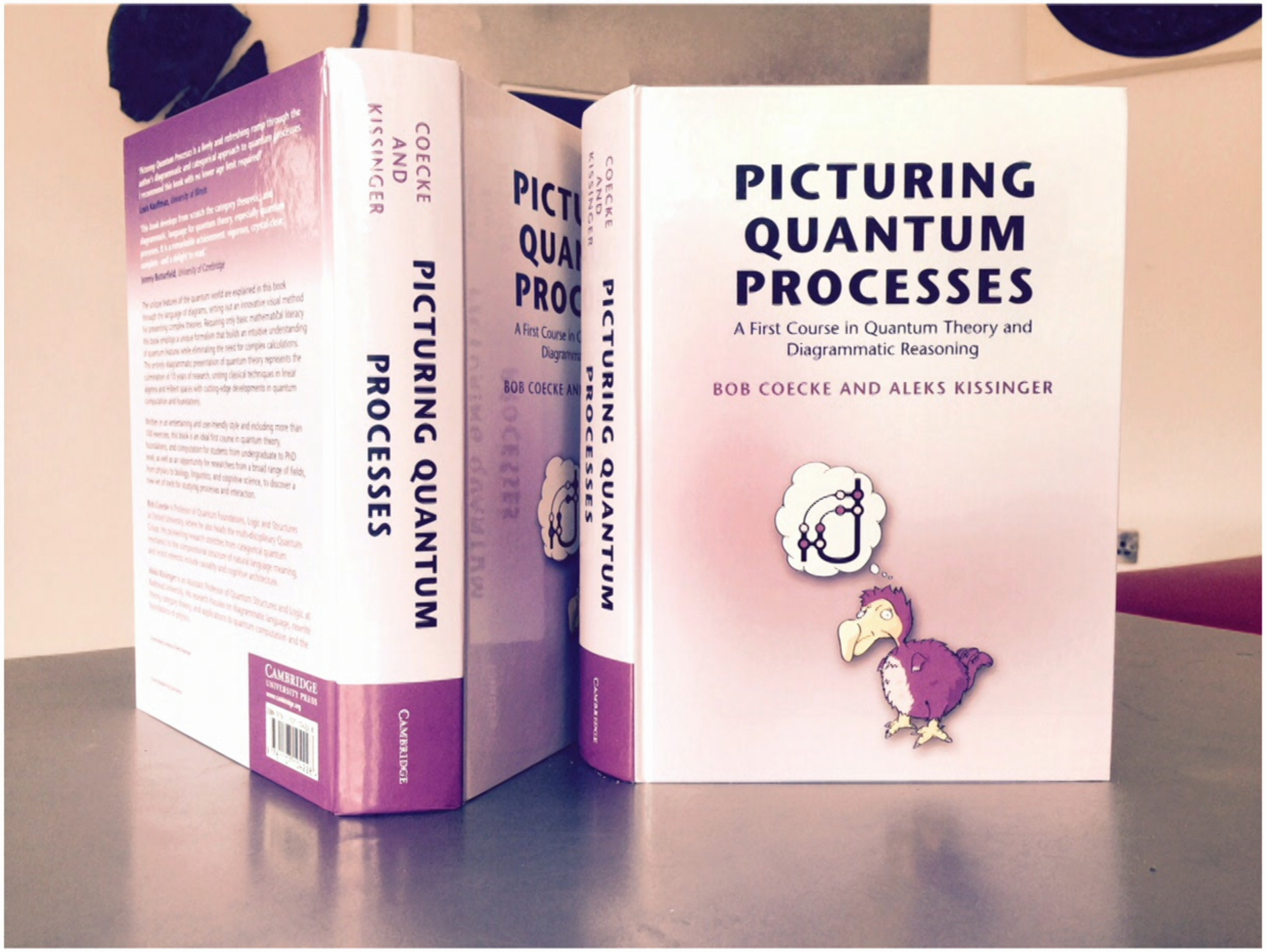
[Submitted on 4 Oct 2005]

Kindergarten Quantum Mechanics

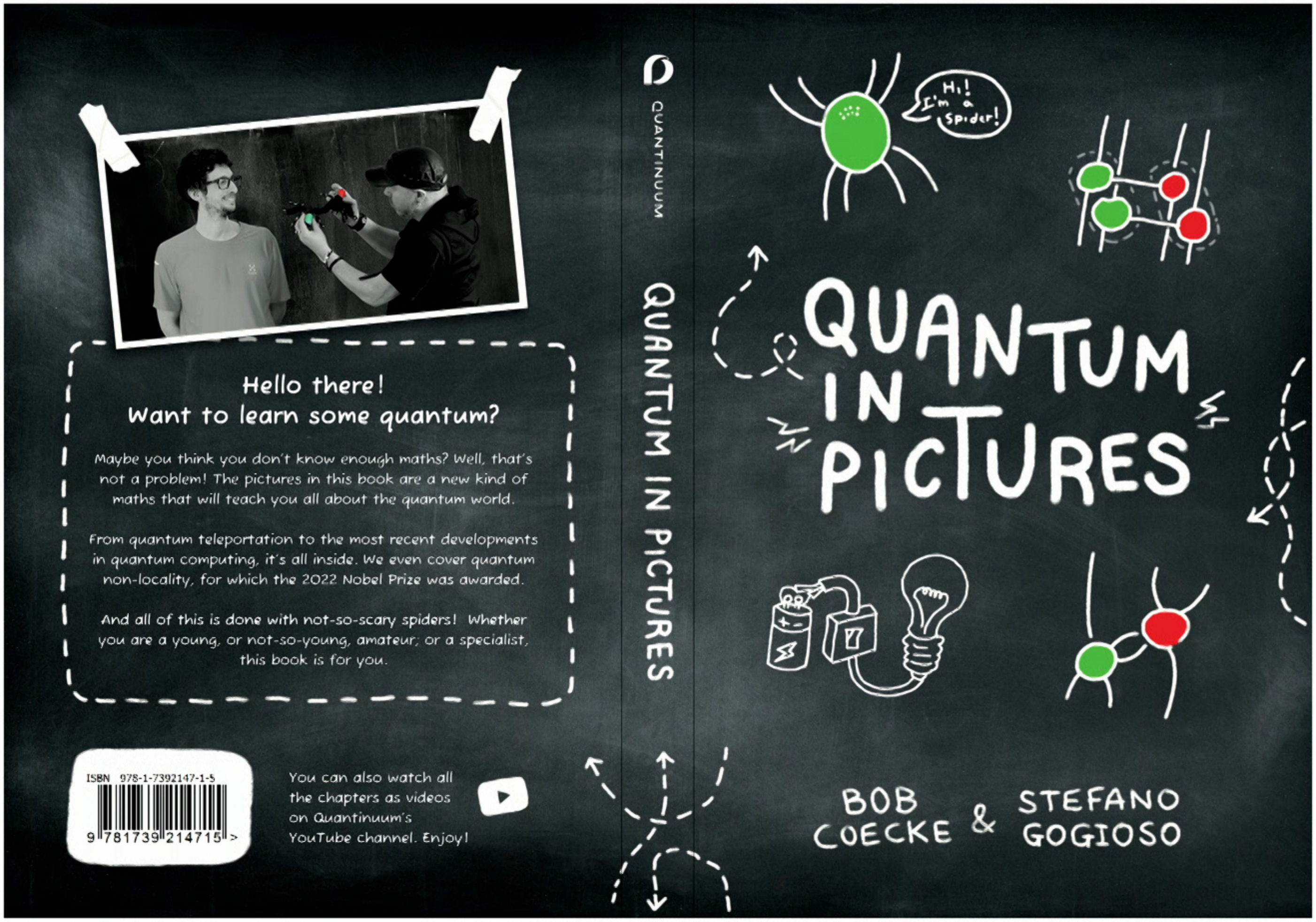
Bob Coecke

These lecture notes survey some joint work with Samson Abramsky as it was presented by me at several conferences in the summer of 2005. It concerns `doing quantum mechanics using only pictures of lines, squares, triangles and diamonds'. This picture calculus can be seen as a very substantial extension of Dirac's notation, and has a purely algebraic counterpart in terms of so-called Strongly Compact Closed Categories (introduced by Abramsky and I in quant-ph/0402130 and [4]) which subsumes my Logic of Entanglement quant-ph/0402014. For a survey on the `what', the `why' and the `hows' I refer to a previous set of lecture notes quant-ph/0506132. In a last section we provide some pointers to the body of technical literature on the subject.

...13 years later...


PICTURING QUANTUM PROCESSES
A First Course in Quantum Theory and Diagrammatic Reasoning
BOB COECKE AND ALEKS KISSINGER
COECKE AND KISSINGER
PICTURING QUANTUM PROCESSES
CAMBRIDGE

...5 years later...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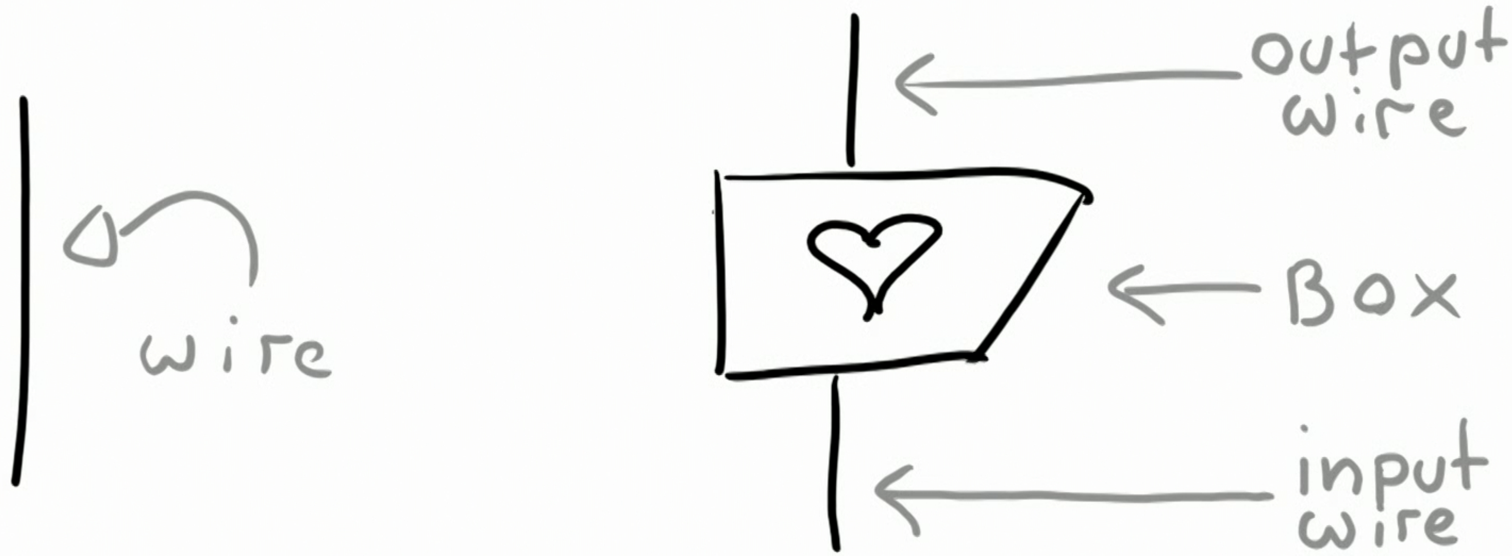
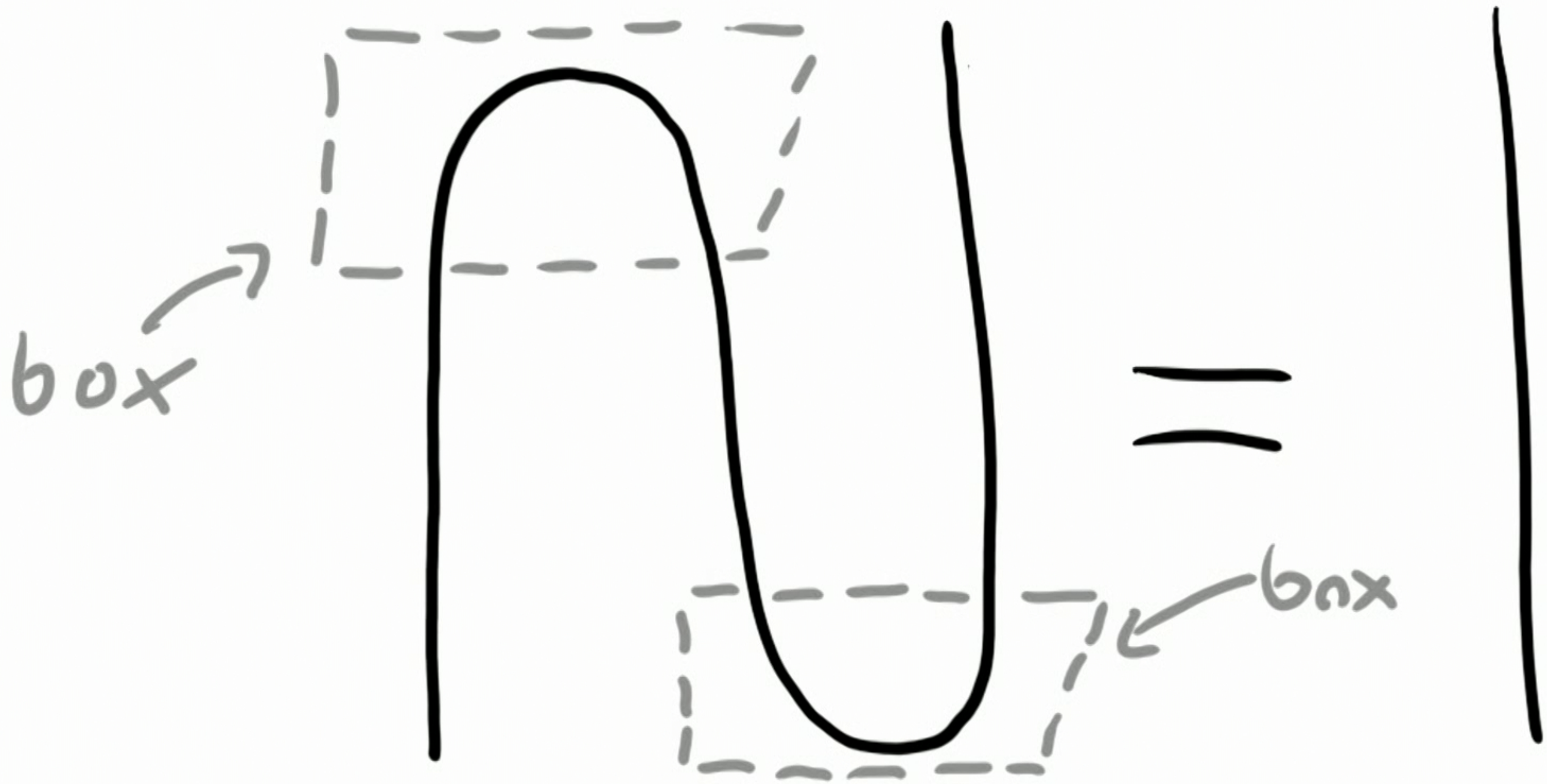
QUANTUM IN PICTURES
BOB COECKE & STEFANO GOGIOSO

– wires and boxes as mathematics –



– cup and cap boxes –



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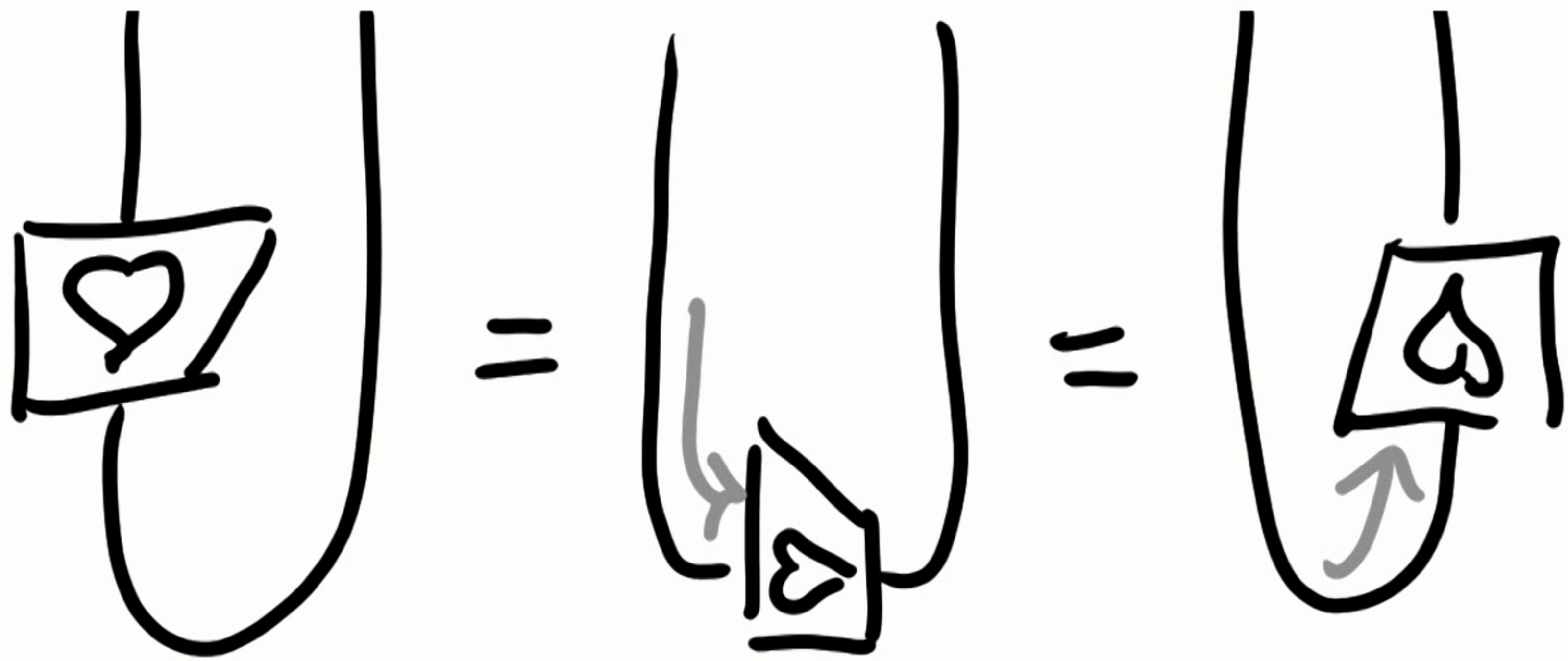
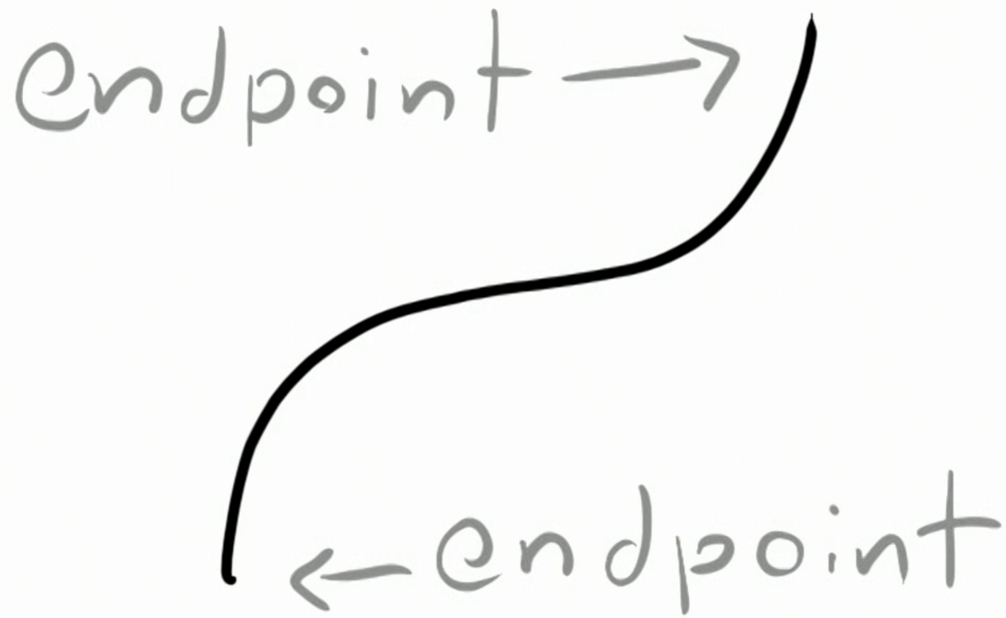


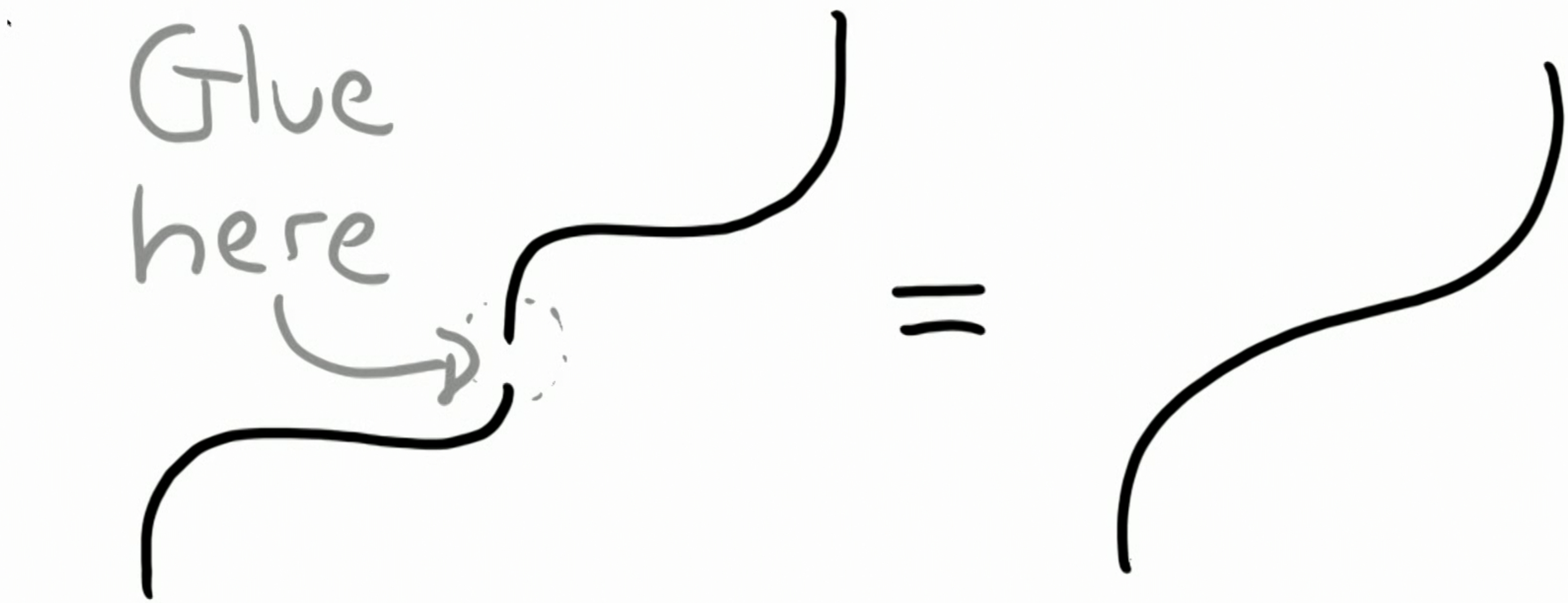
– teleportation –

Chapter 2: spiders is all you need

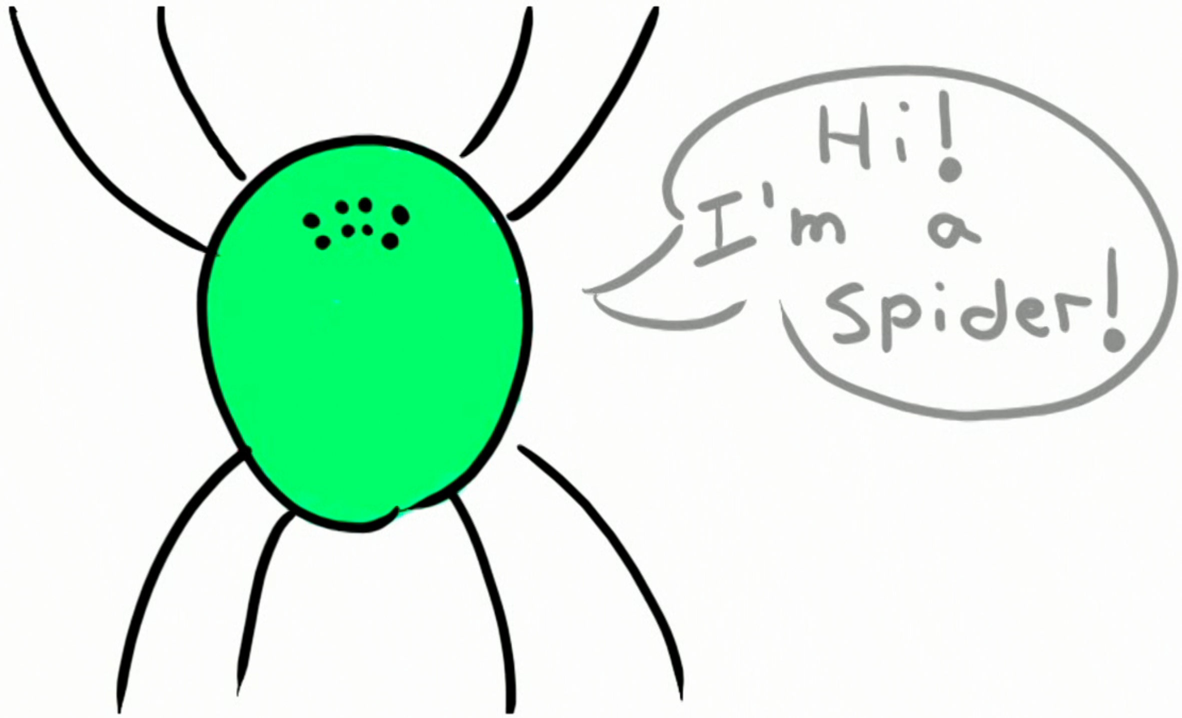
– from wires to spiders –



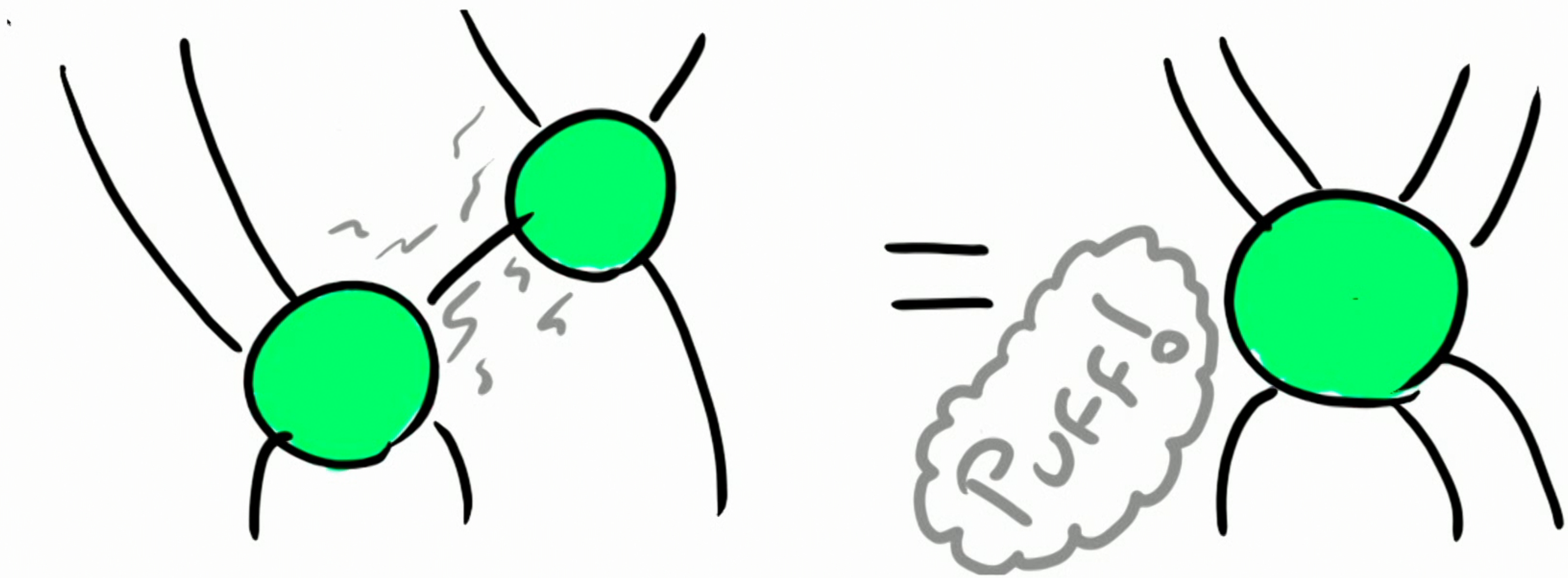
– from wires to spiders –



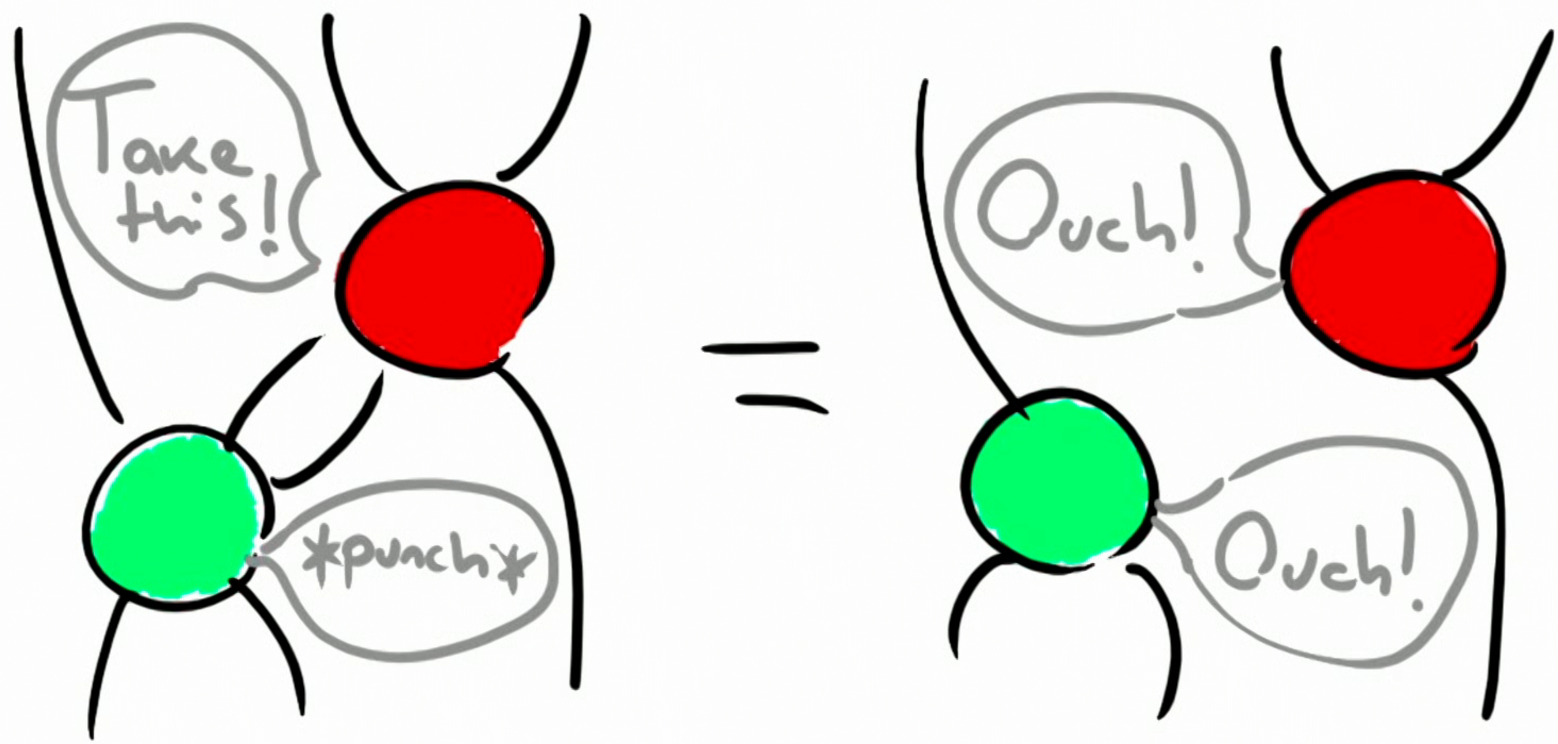
– from wires to spiders –



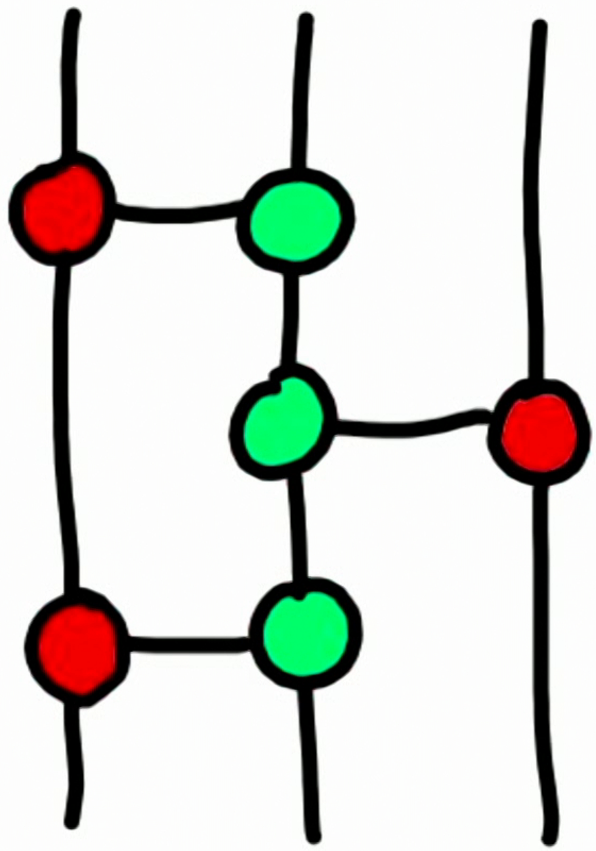
– from wires to spiders –

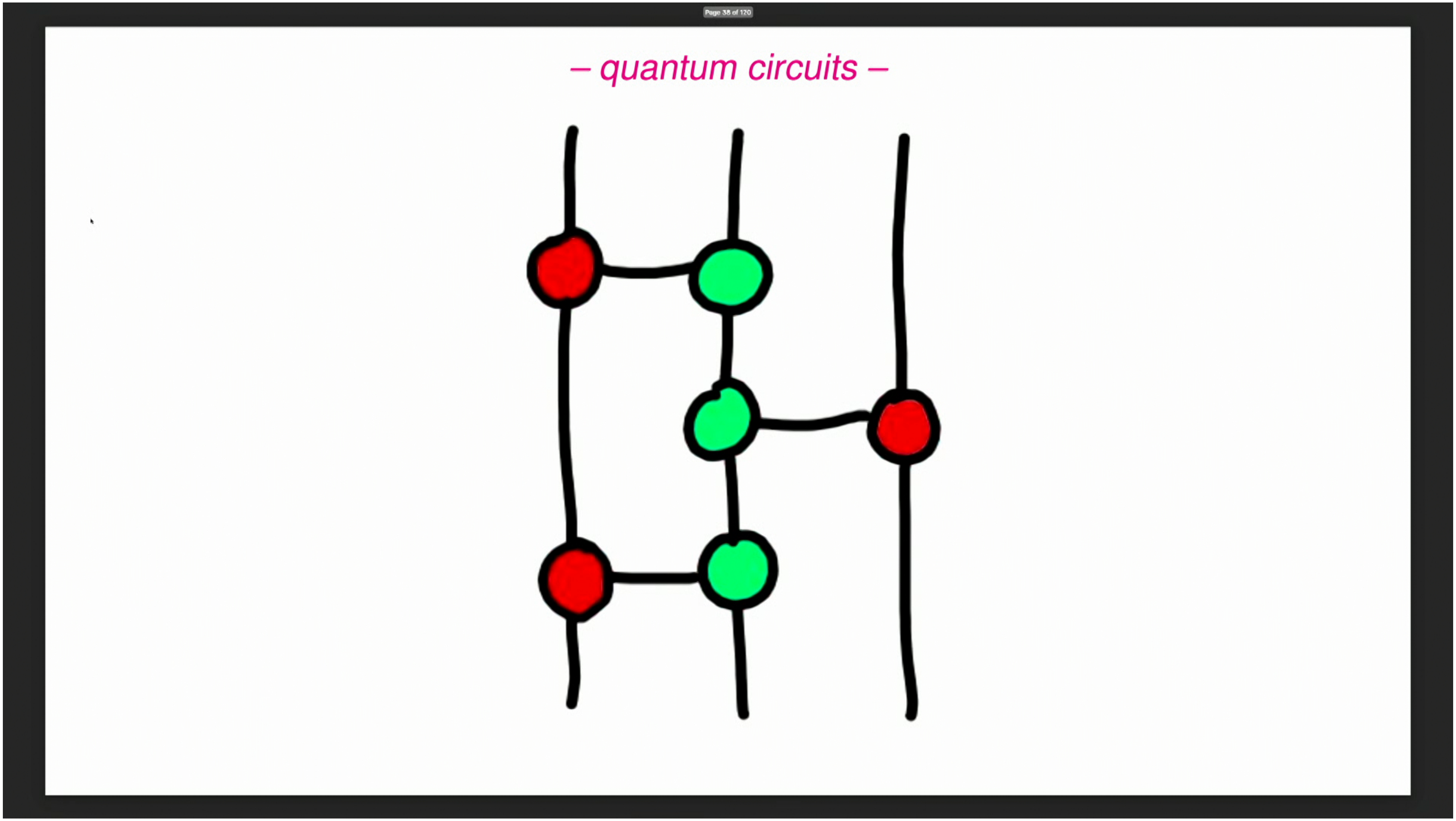


– coloured spiders –

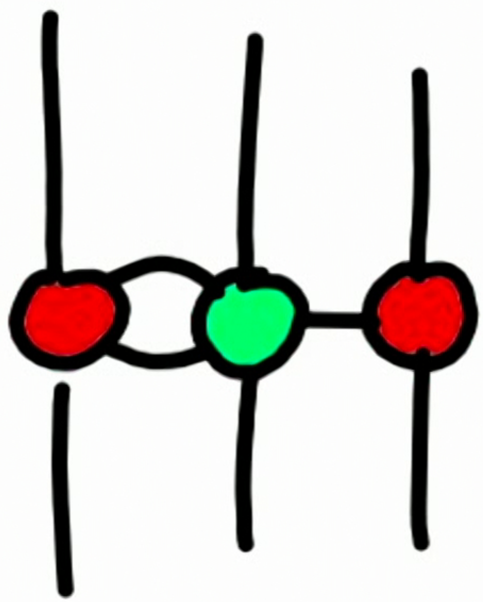


– quantum circuits –




Page 38 of 120
– quantum circuits –

– quantum circuits –



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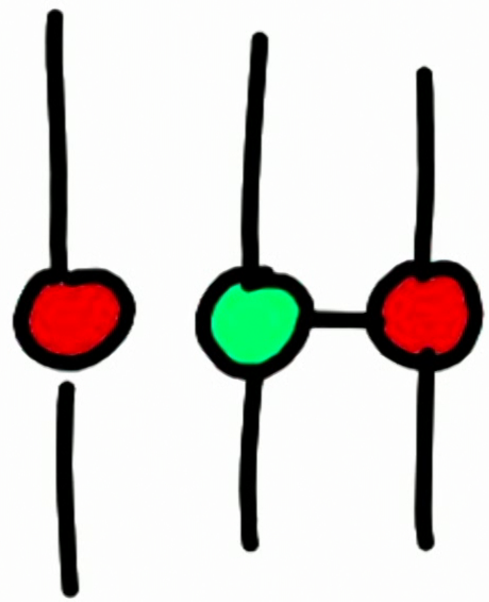
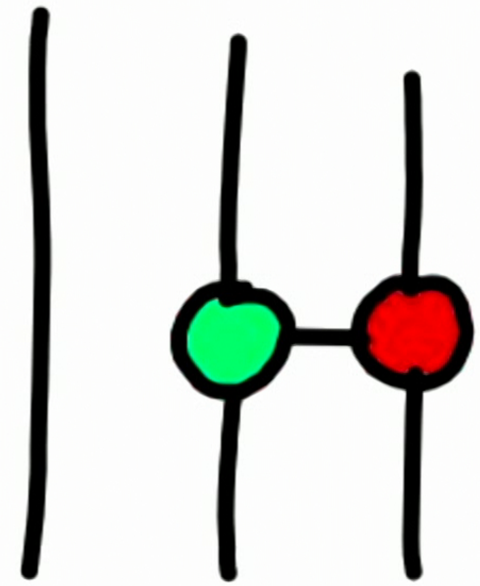
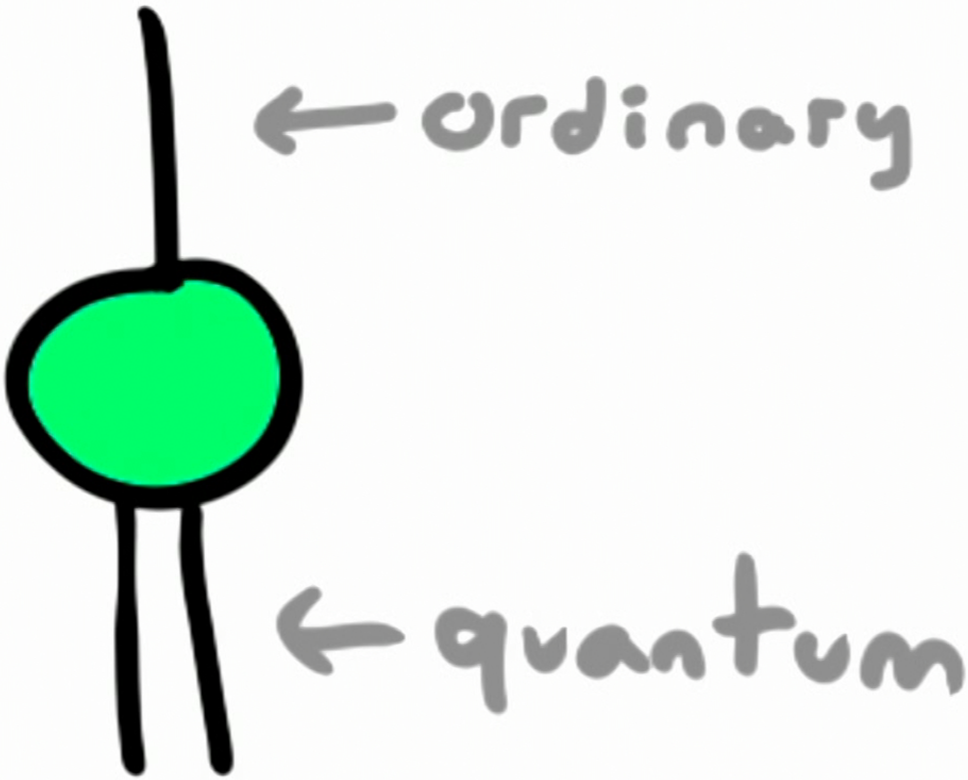


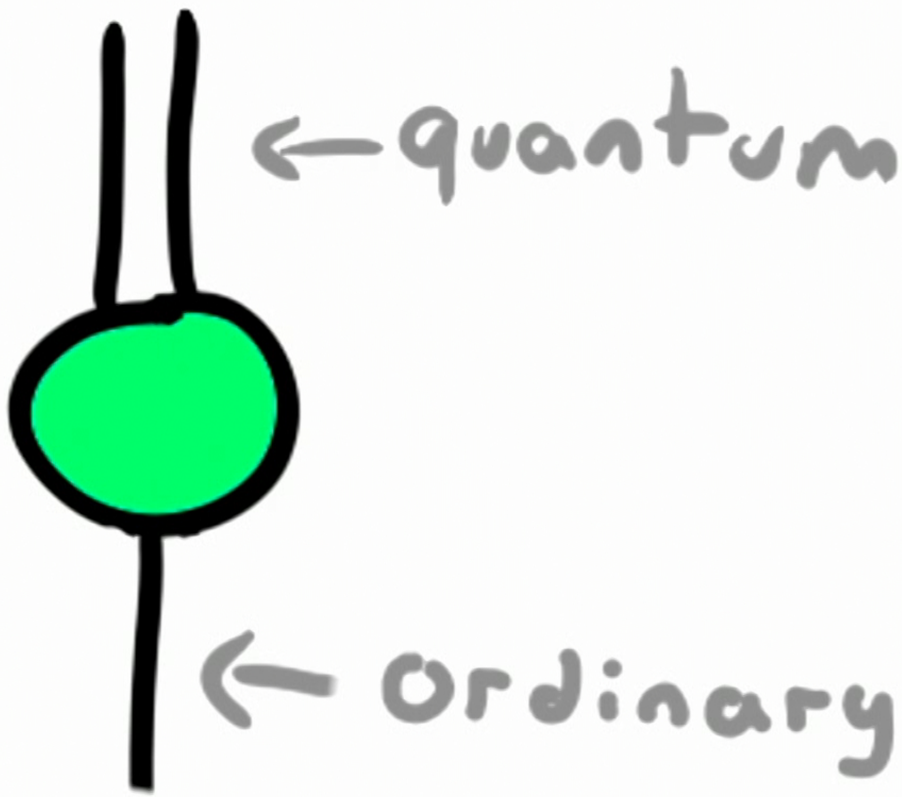
– quantum circuits –



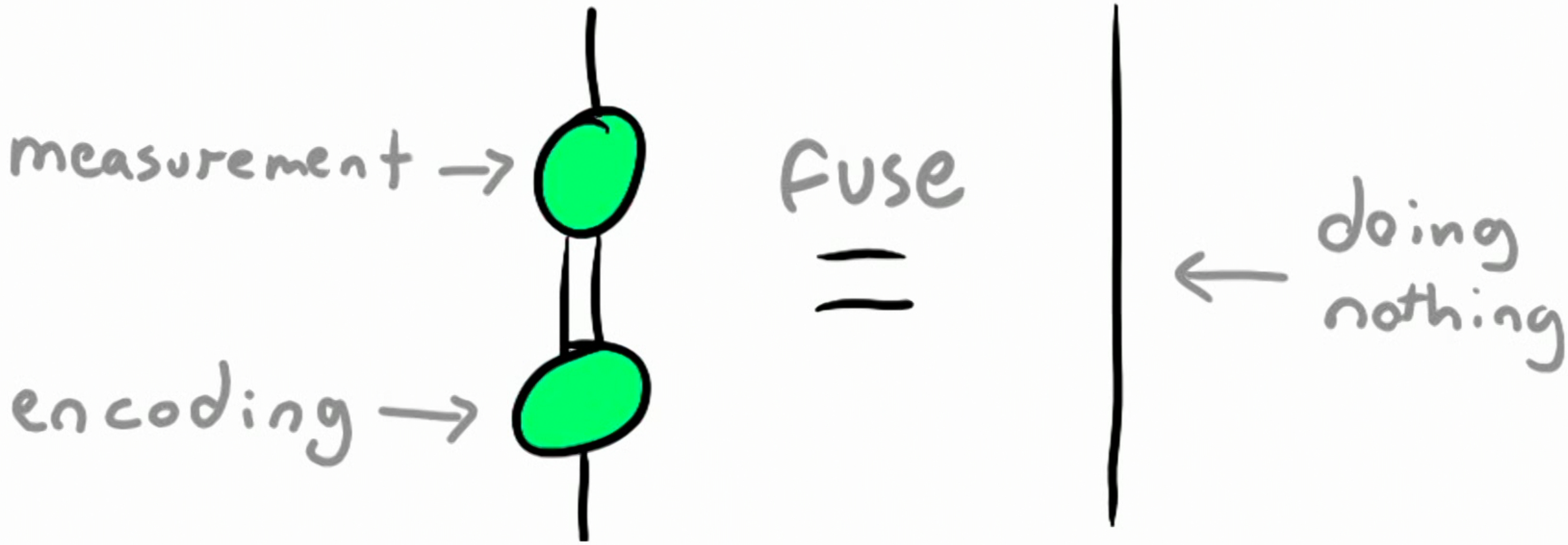
– measurement –



– encoding –



– measurement after encoding –



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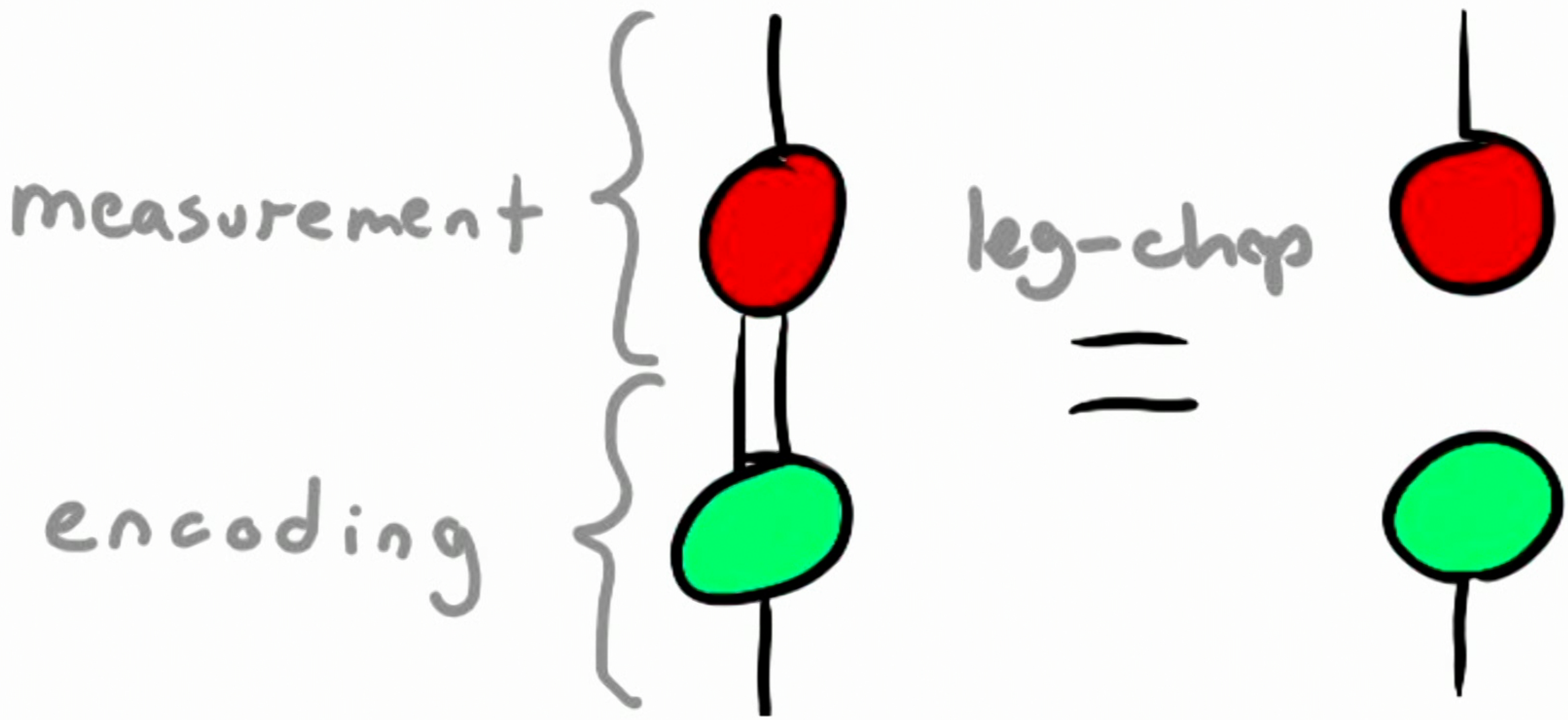
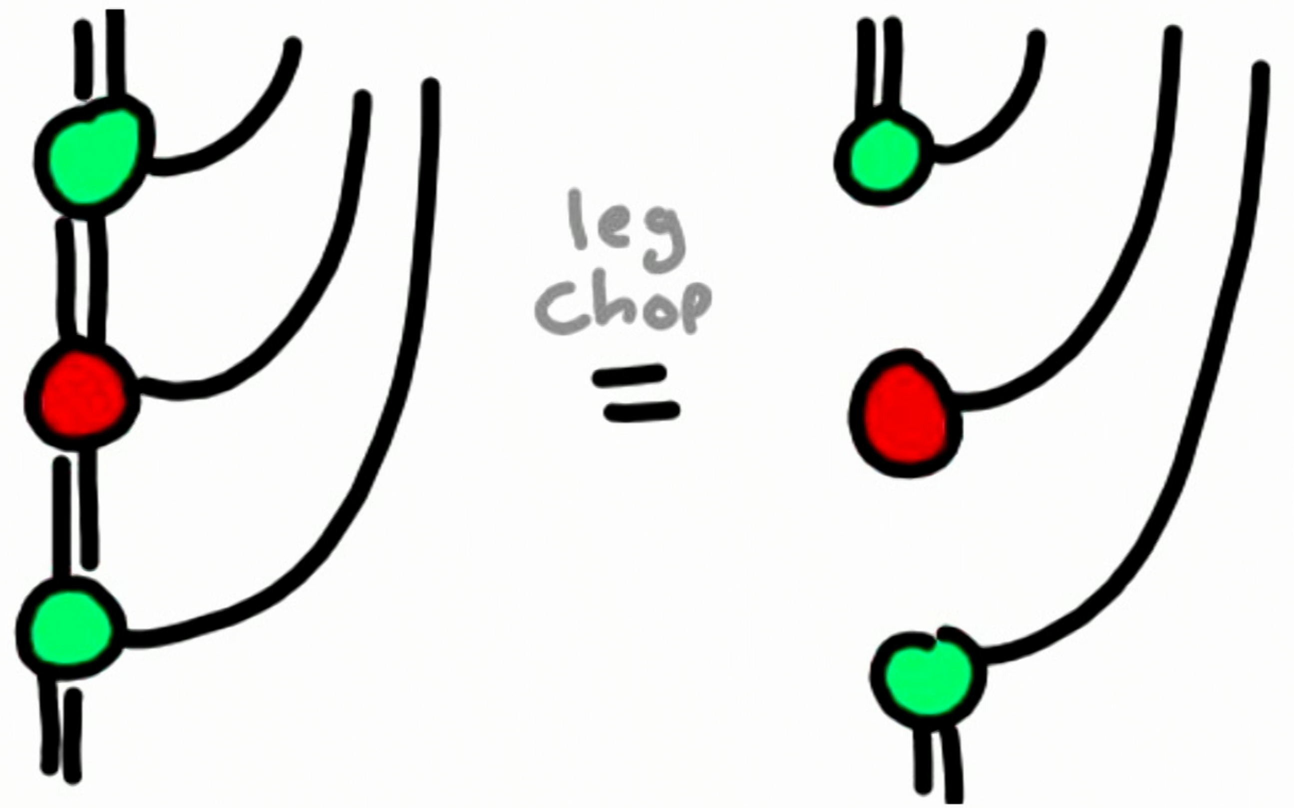
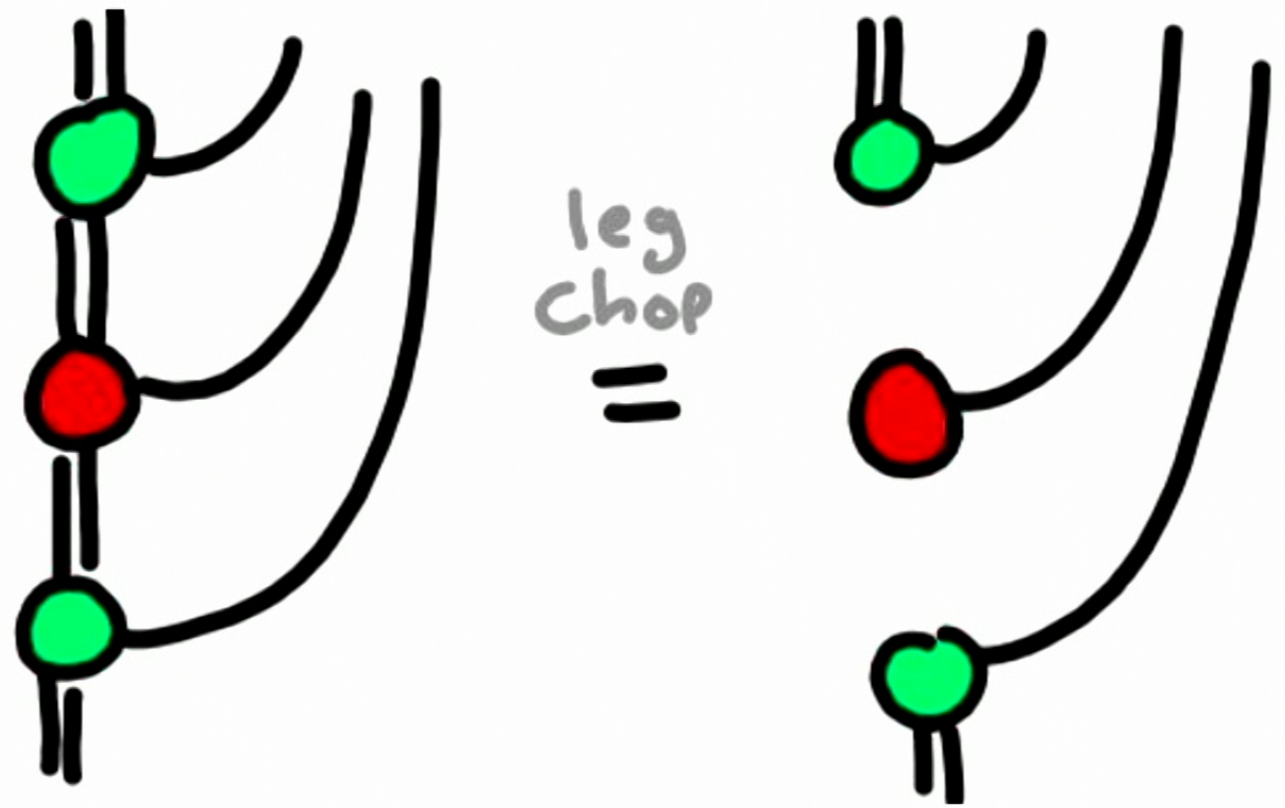


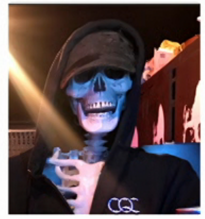
– measurement after measurement after measurement –



– measurement after measurement after measurement –



ZX-calculus (2023) - in a few toilet sittings



arXiv > quant-ph > arXiv:2303.03163

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Quantum Physics

[Submitted on 6 Mar 2023]

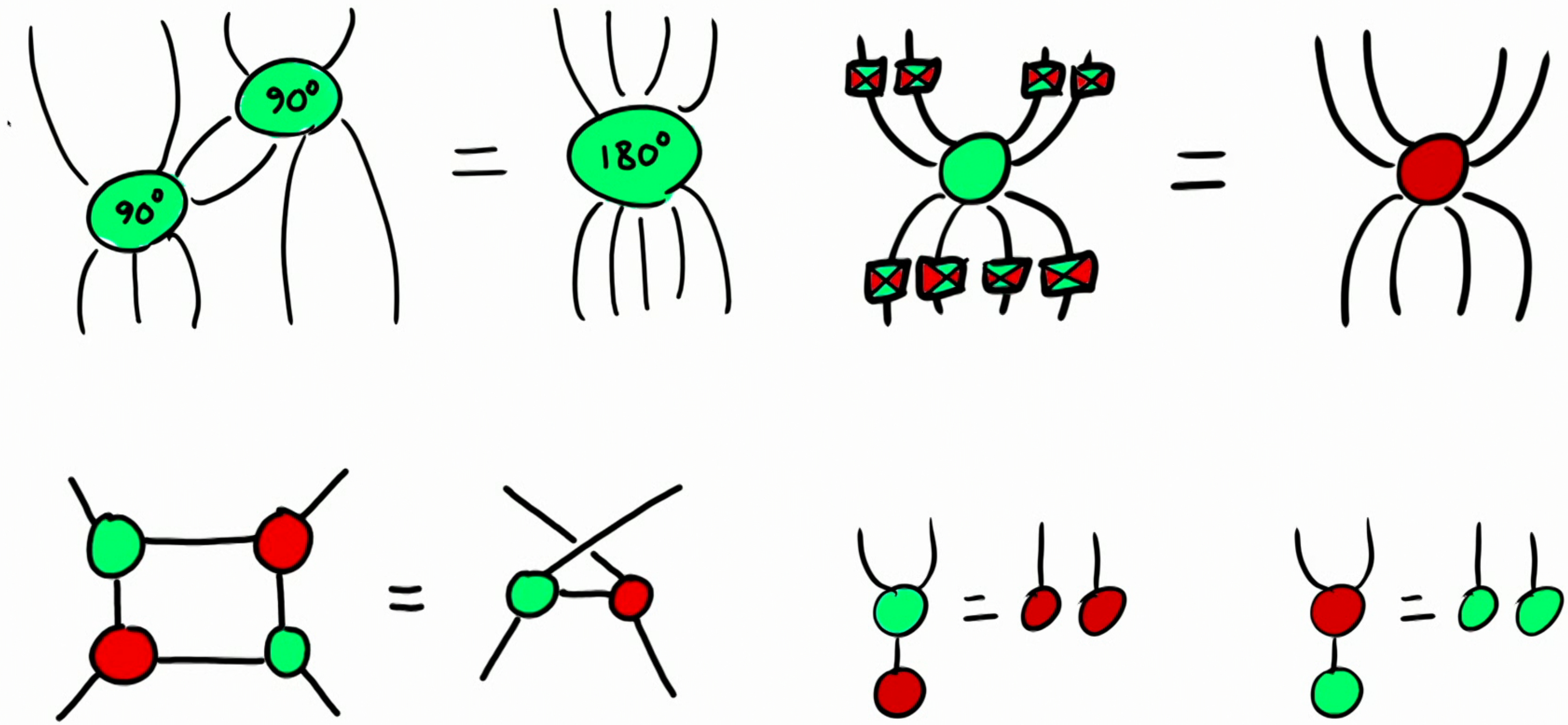
Basic ZX-calculus for students and professionals

Bob Coecke

These are the lecture notes of guest lectures for Artur Ekert's course Introduction to Quantum Information at the Mathematical Institute of Oxford University, Hilary Term 2023. Some basic familiarity with Dirac notation is assumed. For the readers of Quantum in Pictures (QiP) who have some basic quantum background, these notes also constitute the shortest path to an explanation of how what they learn in QIP relates to the traditional quantum formalism.

Comments: 29 pages and lost of pictures

– "ZX-calculus" –



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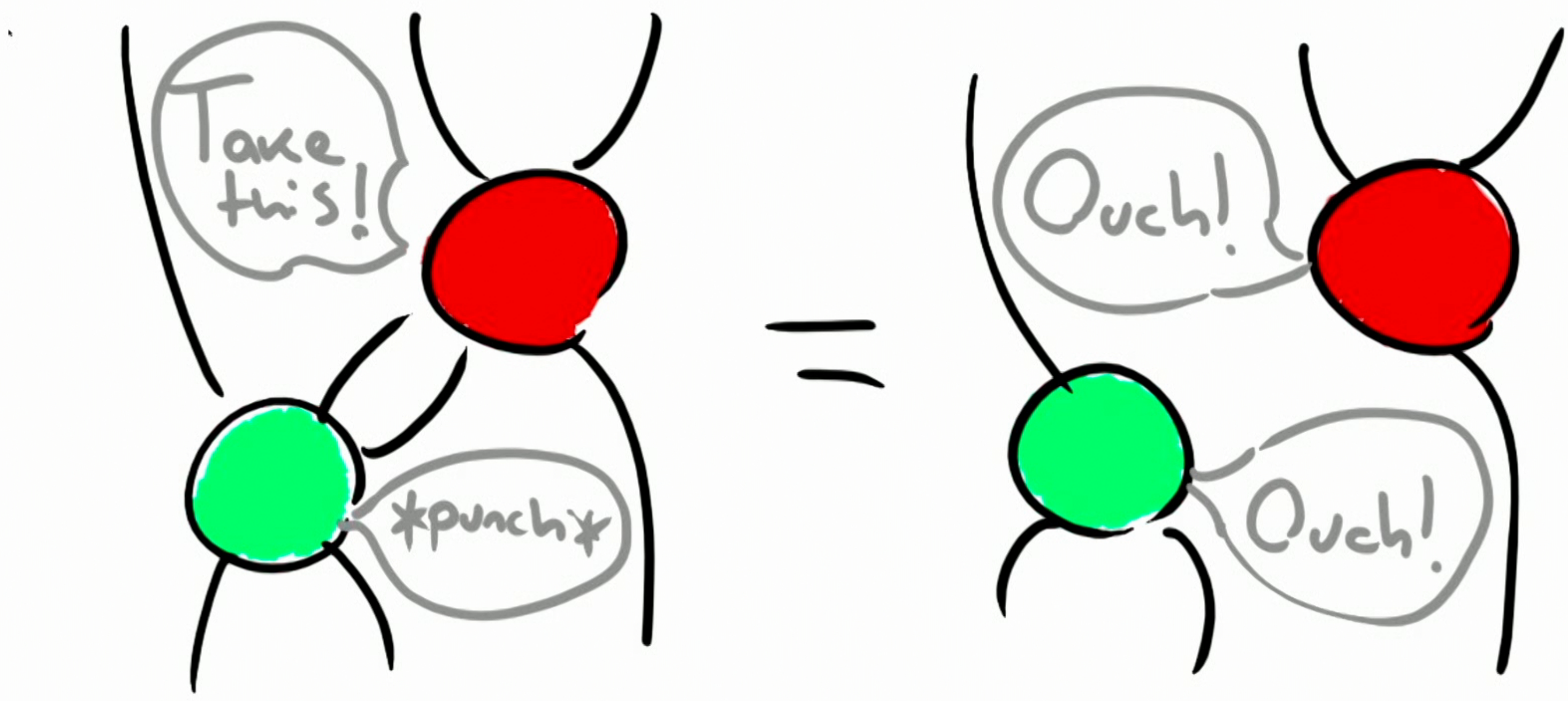
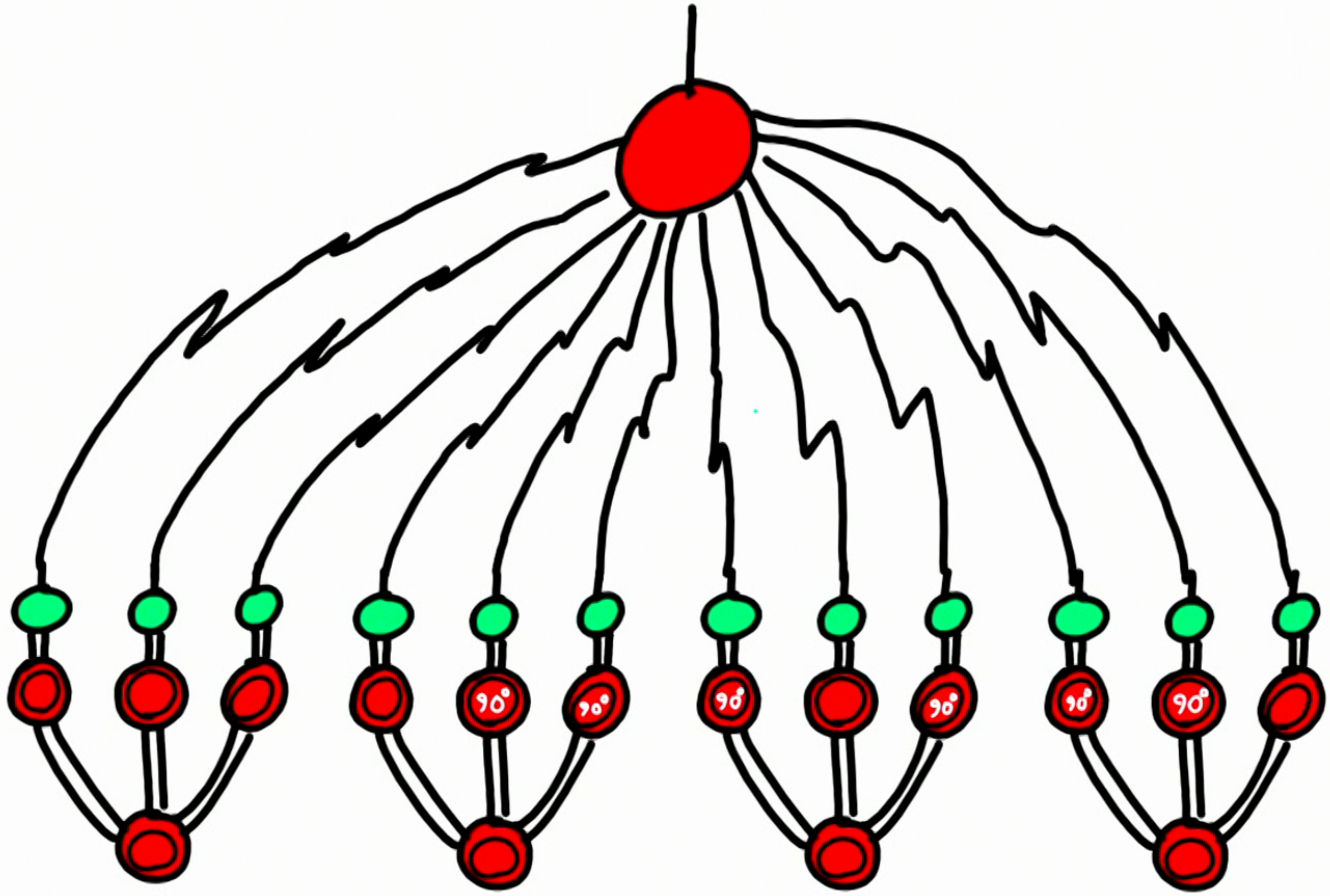
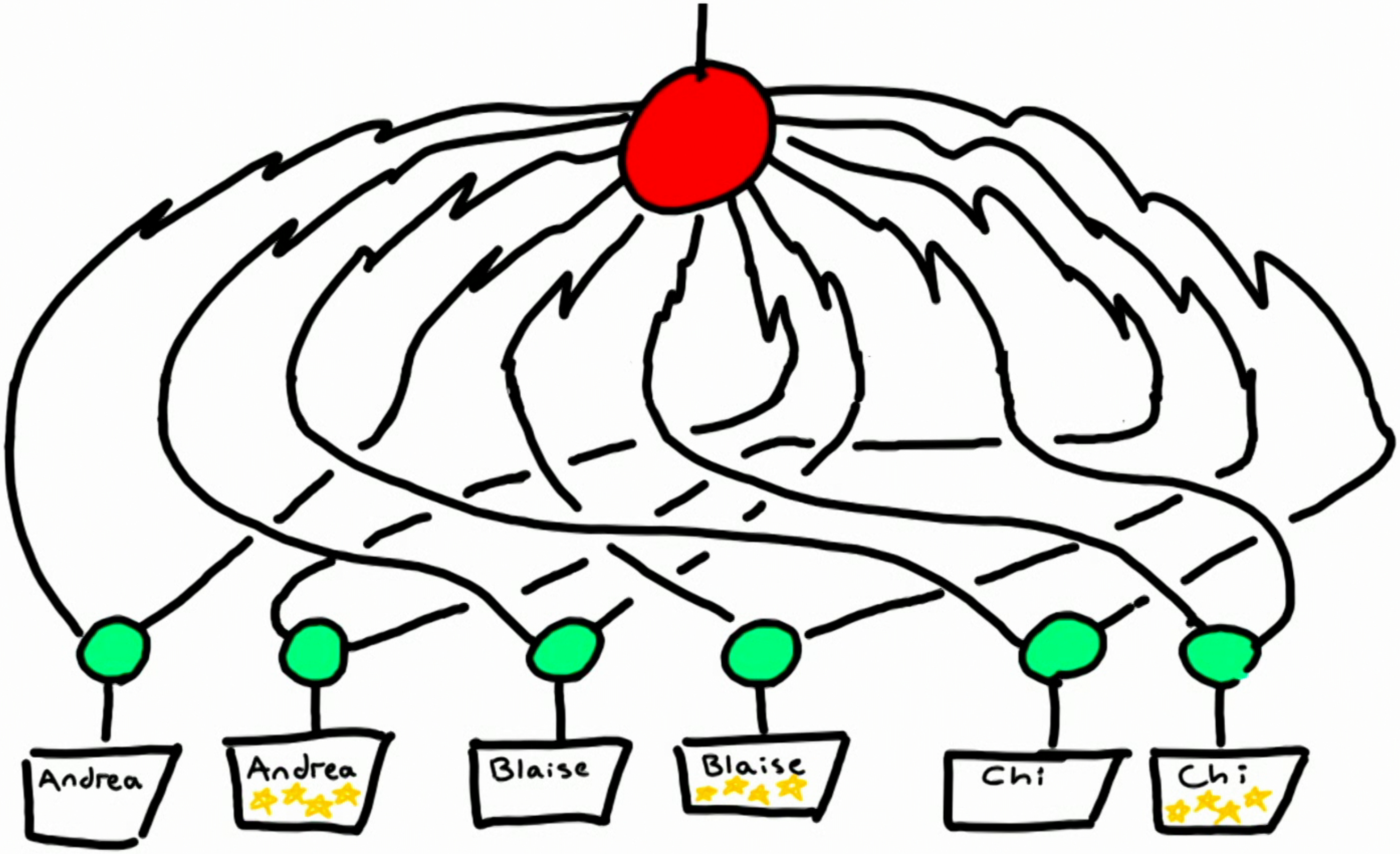


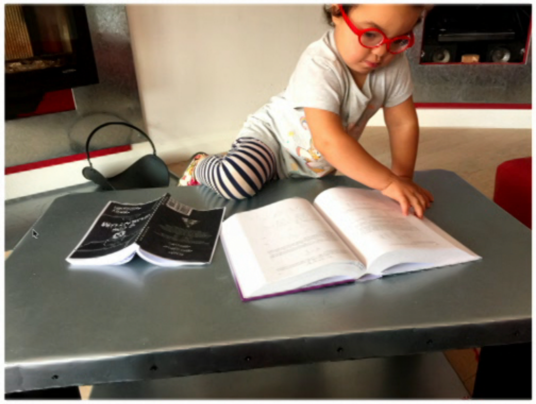
– 2022 Nobel Prize –



– 2022 Nobel Prize –




BOB COECKE & STEFANO GOGIOSO
Dan Razvan Ghica
Yesterday at 07:45 ·
Strong positive reviews from Alexander Ghica (age 10) on Bob Coecke 's new book. "Very clear", "very well structured" (yeah, he actually said that 😅) and "easier to understand than science YouTube videos".



KIDS OUTPERFORM OXFORD UNIVERSITY STUDENTS!!!

– quantum error correction –

Graphical quantum Clifford-encoder compilers from the ZX calculus

Andrey Boris Khesin,[1,*] Jonathan Z. Lu,[2,†] and Peter W. Shor[1,‡]

[1] *Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA*

[2] *Department of Physics, Harvard University, Cambridge, MA*

(Dated: January 9, 2023)

Building Blocks — Our main tool is the ZX-calculus, a graphical language for vectors that has become of great interest in quantum information research [26–30]. The ZX-calculus produces visual di-

circuit optim

QUANTINUUM, NASA, PwC, DLR, Automatski, Terra Quantum, USRA

optical MBQC

QUANTINUUM, QUANDELA, PsiQ, XANADU, ORCA COMPUTING

error-corr/surg

QUANTINUUM, PsiQ, Google

q-crypto

NIST National Institute of Standards and Technology U.S. Department of Commerce

other

QUANTINUUM, WOLFRAM, Los Alamos NATIONAL LABORATORY

pro education

QUANTINUUM, IBM

mass education

QUANTINUUM, IBM

quantum AI

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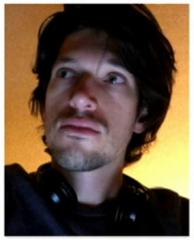
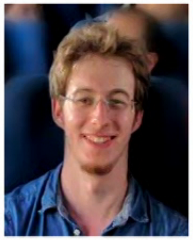
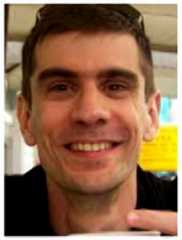
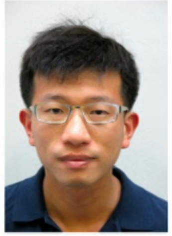
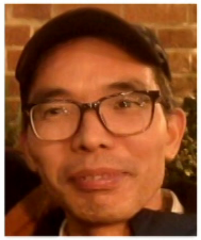
chem/bio

QUANTINUUM, AMGEN

Completeness!

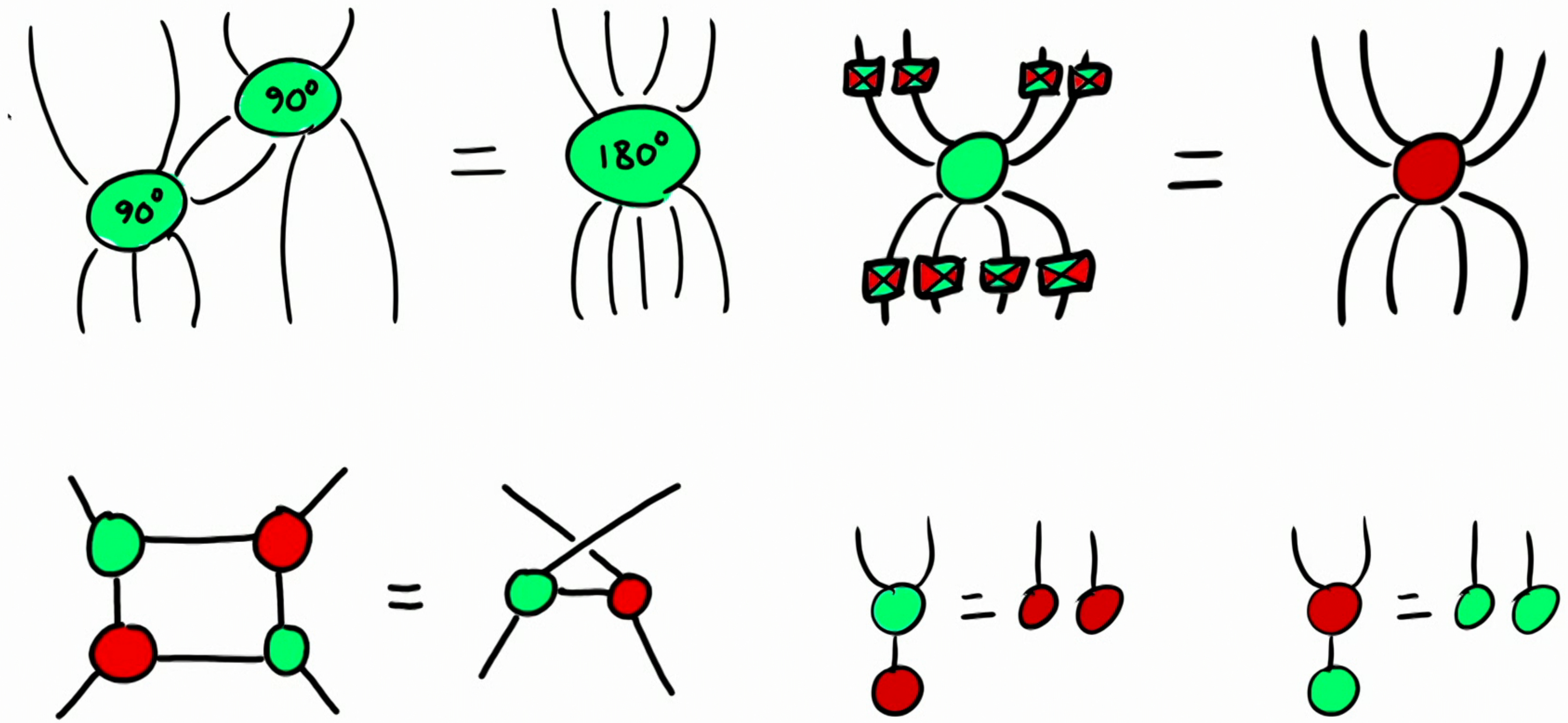
Two complete axiomatisations of pure-state qubit quantum computing

Authors: Amar Hadzihasanovic, Kang Feng Ng, Quanlong Wang Authors Info & Claims

LICS '18: Proceedings of the 33rd Annual ACM/IEEE Symposium on Logic in Computer Science • July 2018 • Pages 502–511 • https://doi.org/10.1145/3209108.3209128

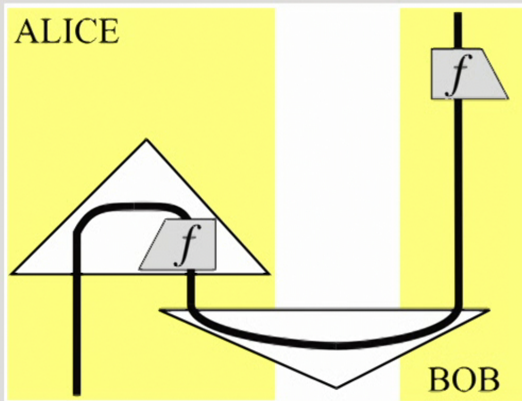
Online: 09 July 2018 Publication History

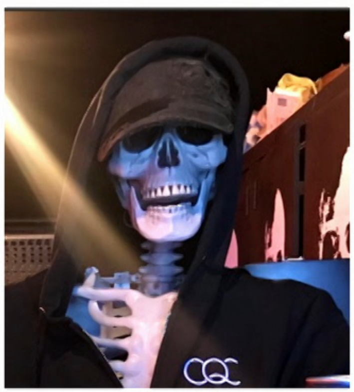
– "ZX-calculus" –



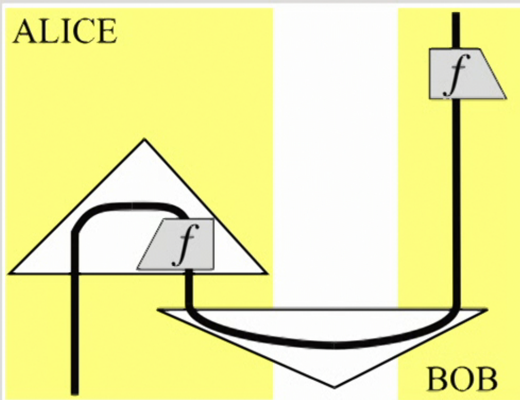
Jim Lambek

Hello, I present to you quantum teleportation:



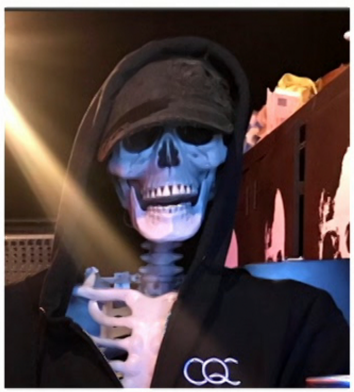


Hello, I present to you quantum teleportation:



Bob!

This is grammar!

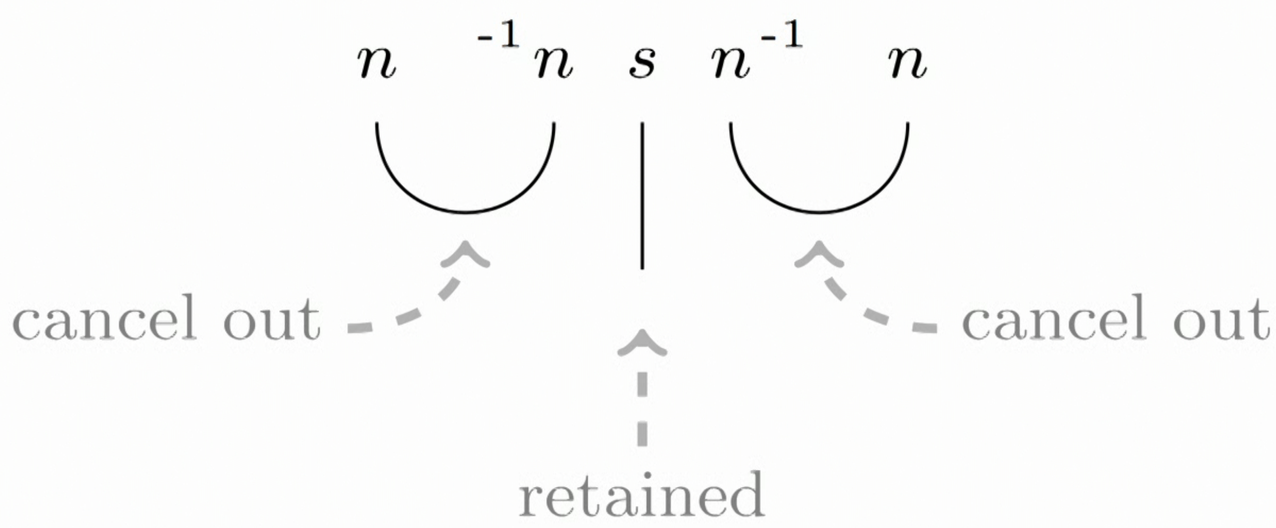


grammar algebra

For noun type n, sentence type s, verb type is ${}^{-1}n \cdot s \cdot n^{-1}$, so:

$$n \cdot {}^{-1}n \cdot s \cdot n^{-1} \cdot n \leq s$$

As a diagram:

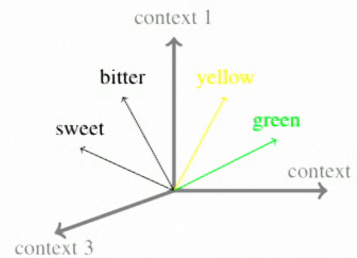


Colleagues @ Oxford University

- ...knew **grammar mathematics**:

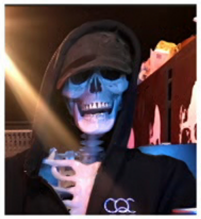
$$n \cdot {}^{-1}n \cdot s \cdot n^{-1} \cdot n \leq 1 \cdot s \cdot 1 \leq s$$

- ...knew **meaning mathematics**:



How combine grammar and meaning?

A new model of language



arXiv.org > cs > arXiv:1003.4394

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Computer Science > Computation and Language

[Submitted on 23 Mar 2010]

Mathematical Foundations for a Compositional Distributional Model of Meaning

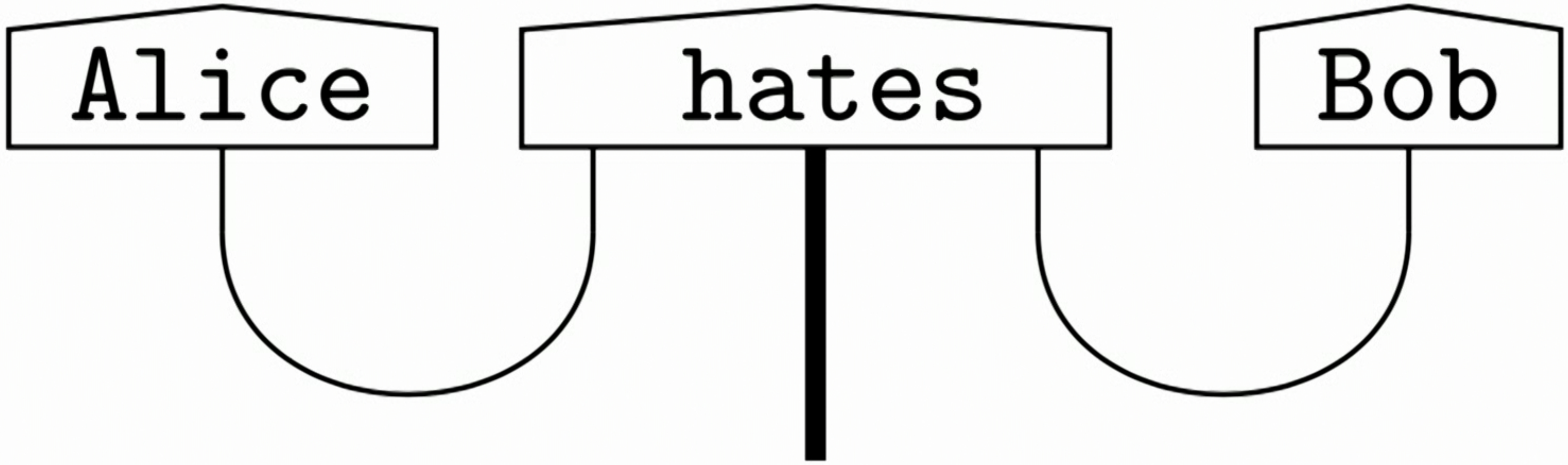
Bob Coecke, Mehrnoosh Sadrzadeh, Stephen Clark

We propose a mathematical framework for a unification of the distributional theory of meaning in terms of vector space models, and a compositional theory for grammatical types, for which we rely on the algebra of Pregroups, introduced by Lambek. This mathematical framework enables us to compute the meaning of a well-typed sentence from the meanings of its constituents. Concretely, the type reductions of Pregroups are `lifted' to morphisms in a category, a procedure that transforms meanings of constituents into a meaning of the (well-typed) whole. Importantly, meanings of whole sentences live in a single space, independent of the grammatical structure of the sentence. Hence the inner-product can be used to compare meanings of arbitrary sentences, as it is for comparing the meanings of words in the distributional model. The mathematical structure we employ admits a purely diagrammatic calculus which exposes how the information flows between the words in a sentence in order to make up the meaning of the whole sentence. A variation of our `categorical model' which involves constraining the scalars of the vector spaces to the semiring of Booleans results in a Montague-style Boolean-valued semantics.

Comments: to appear

Subjects: **Computation and Language (cs.CL)**; Logic in Computer Science (cs.LO); Category Theory (math.CT)

Journal reference: Lambek Festschirft, special issue of Linguistic Analysis, 2010.


Alice
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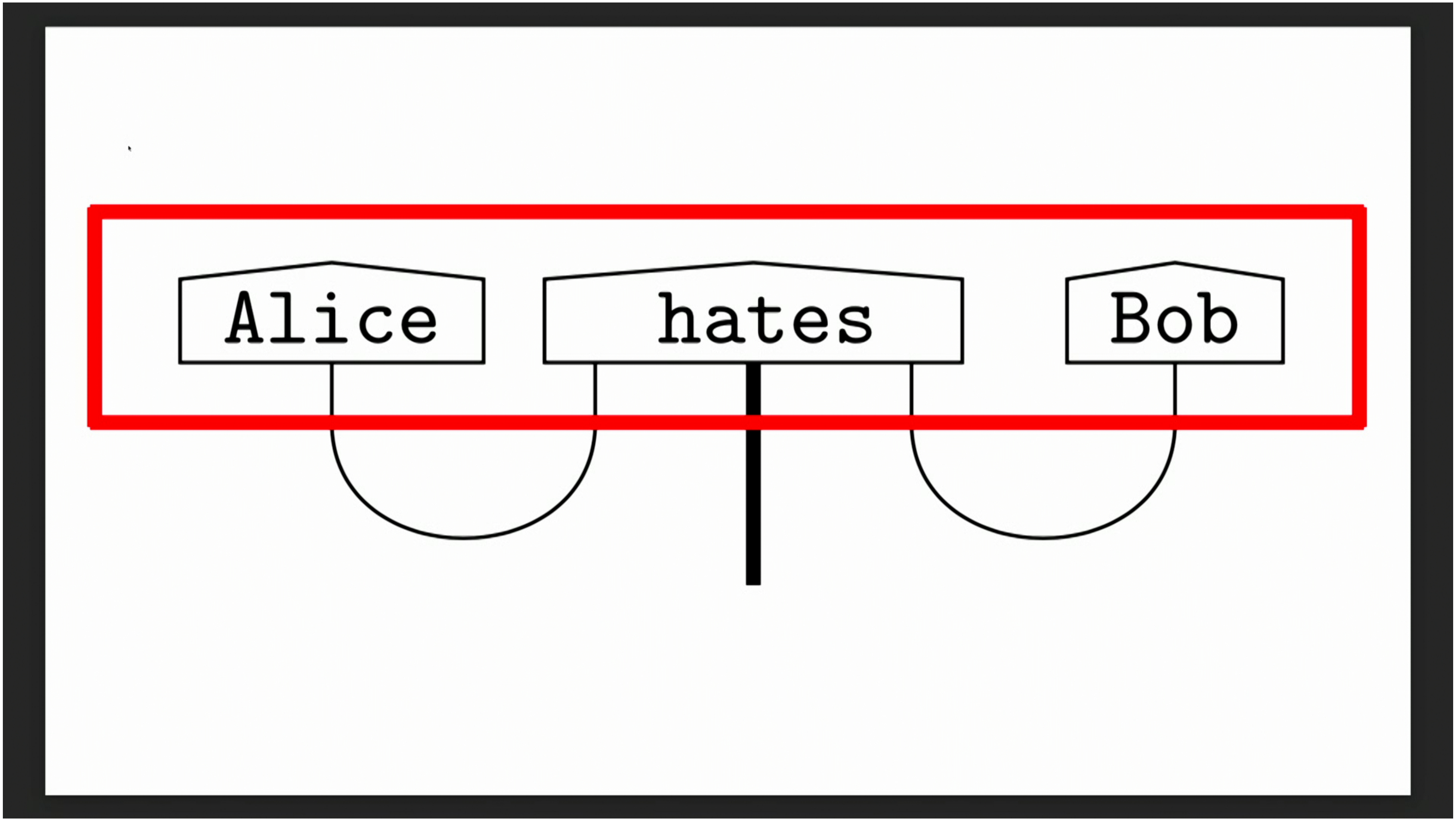
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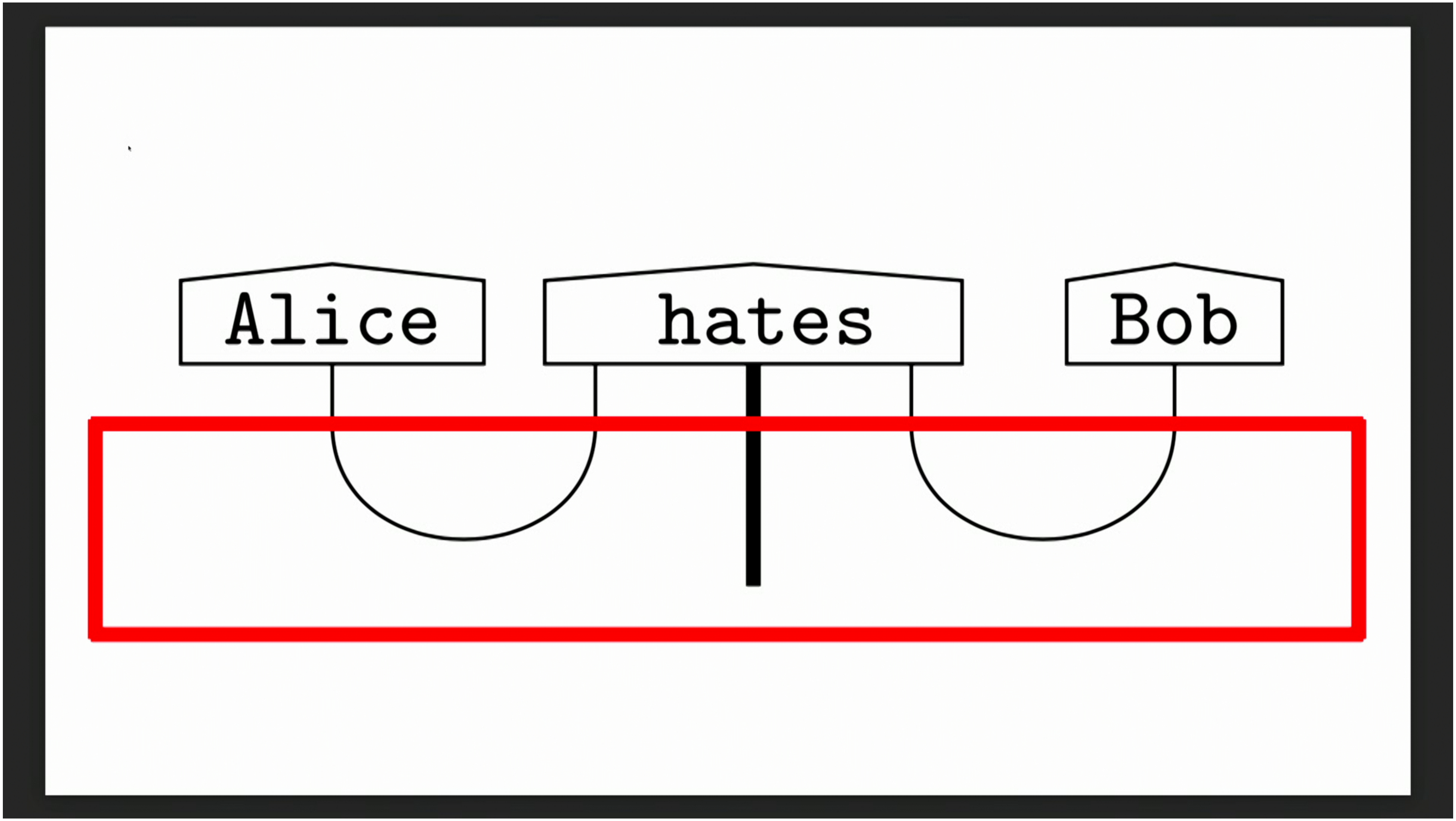
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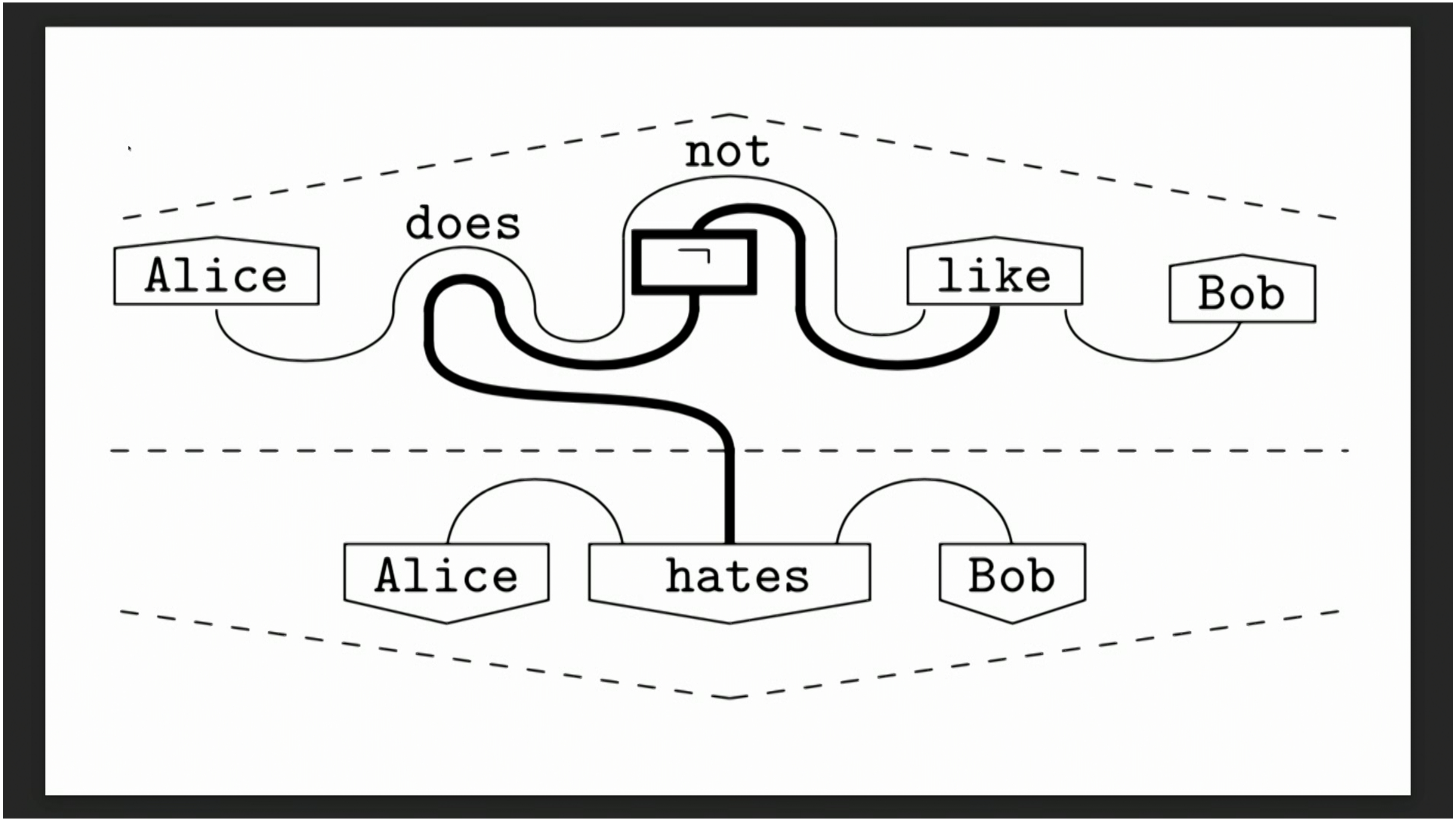
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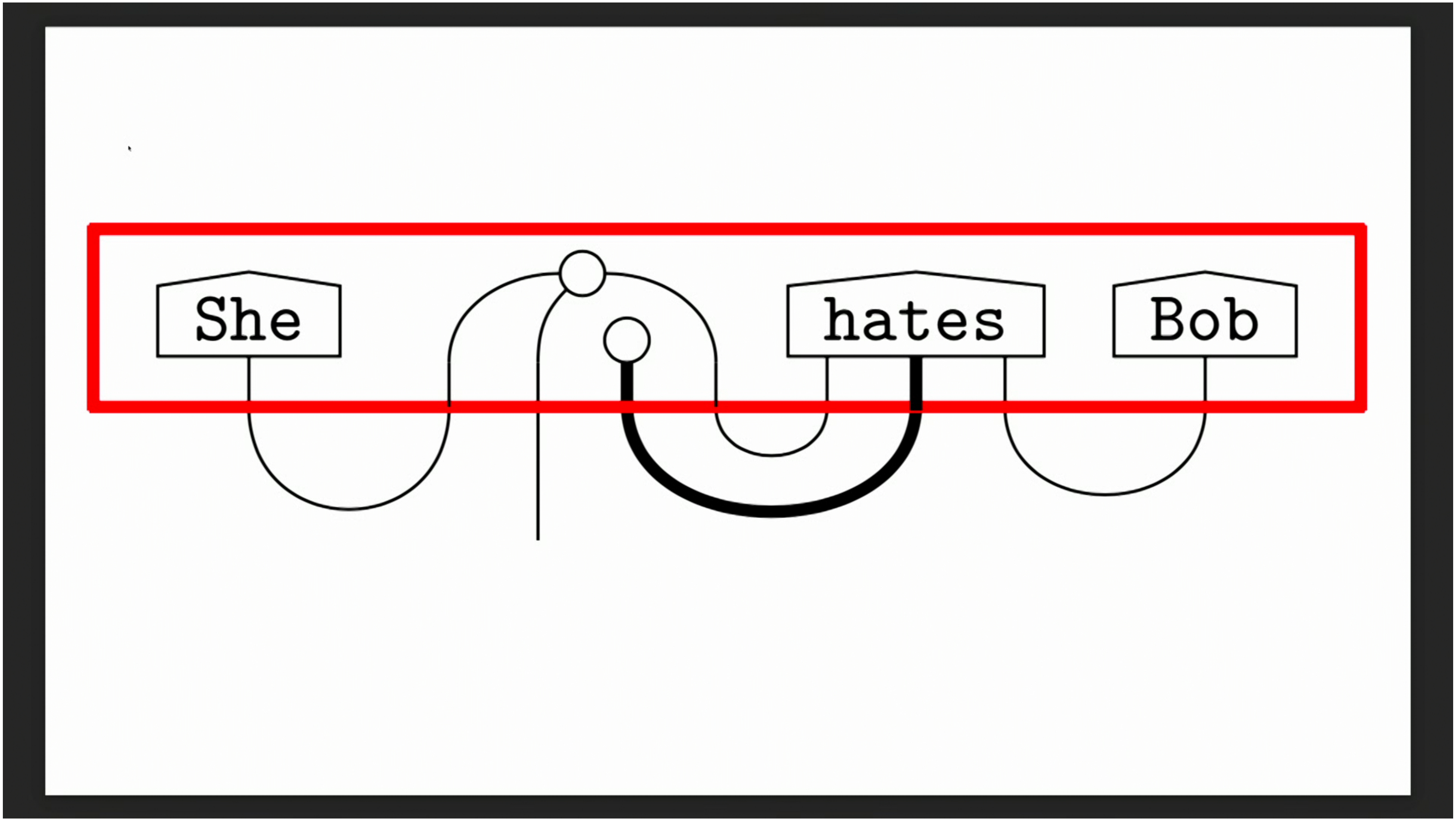
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hates
Bob

QUANTUM LINGUISTICS Leap forward for artificial intelligence

NewScientist

WEEKLY 11 December 2010

FQXI ARTICLE September 29, 2013

Video Article: The Quantum Linguist

Bob Coecke has developed a new visual language that could be used to spell out a theory of quantum gravity—and help us understand human speech.

by Sophie Hebden

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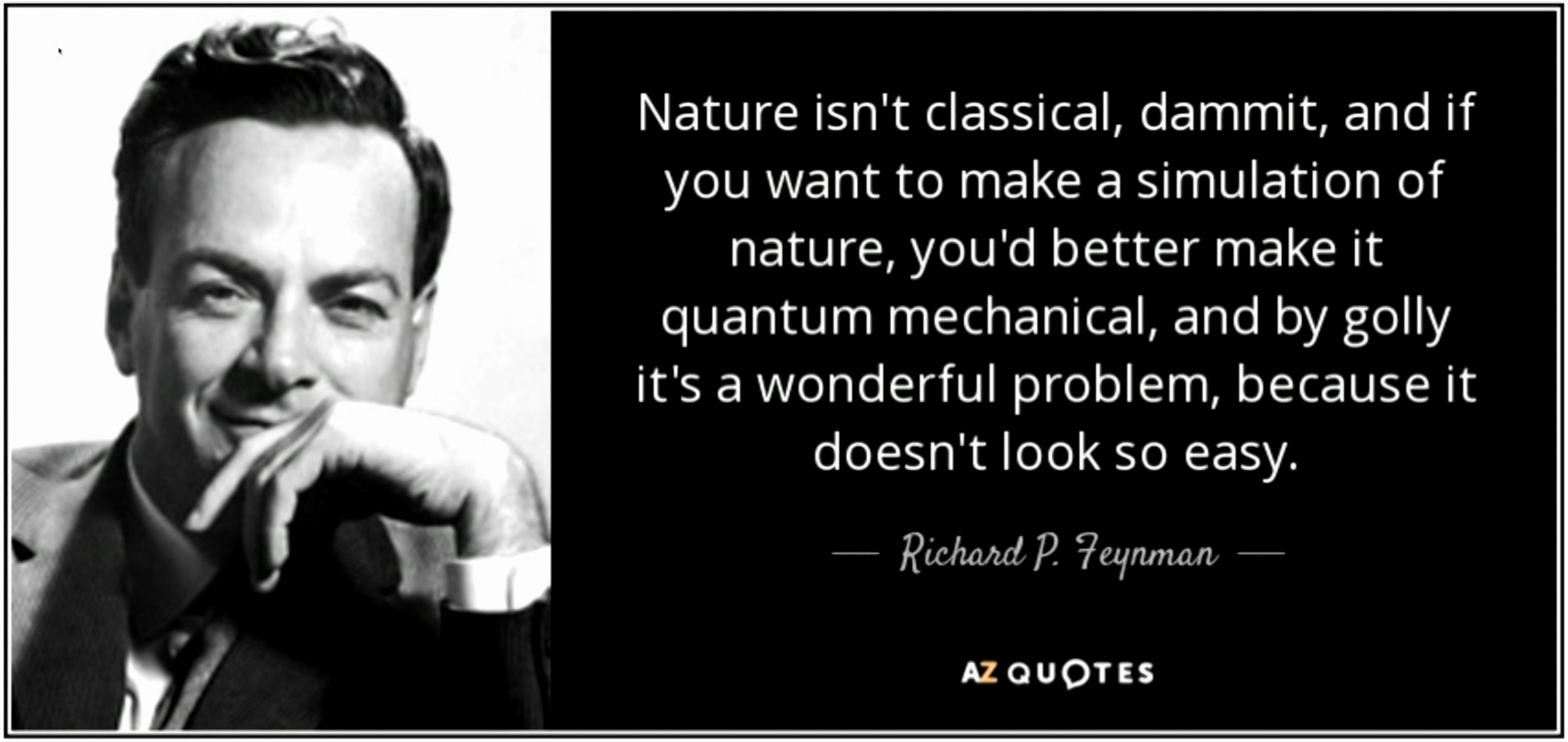
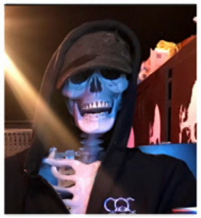
Quantum Mechanical Words and Mathematical Organisms

By Joselle Kehoe | May 16, 2013 | 10


Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy.
— Richard P. Feynman —
AZ QUOTES

Quantum advantage!



arXiv.org > cs > arXiv:1608.01406

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Computer Science > Computation and Language

[Submitted on 4 Aug 2016]

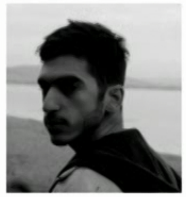
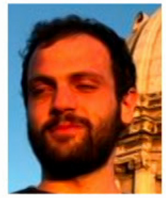
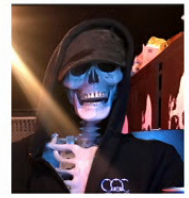
Quantum Algorithms for Compositional Natural Language Processing

William Zeng (Rigetti Computing), Bob Coecke (Univesity of Oxford)

We propose a new application of quantum computing to the field of natural language processing. Ongoing work in this field attempts to incorporate grammatical structure into algorithms that compute meaning. In (Coecke, Sadrzadeh and Clark, 2010), the authors introduce such a model (the CSC model) based on tensor product composition. While this algorithm has many advantages, its implementation is hampered by the large classical computational resources that it requires. In this work we show how computational shortcomings of the CSC approach could be resolved using quantum computation (possibly in addition to existing techniques for dimension reduction). We address the value of quantum RAM (Giovannetti,2008) for this model and extend an algorithm from Wiebe, Braun and Lloyd (2012) into a quantum algorithm to categorize sentences in CSC. Our new algorithm demonstrates a quadratic speedup over classical methods under certain conditions.

Comments: In Proceedings SLPCS 2016, arXiv:1608.01018

Just do it!

arXiv.org > quant-ph > arXiv:2012.03756

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Quantum Physics

[Submitted on 7 Dec 2020]

Grammar-Aware Question-Answering on Quantum Computers

Konstantinos Meichanetzidis, Alexis Toumi, Giovanni de Felice, Bob Coecke

Natural language processing (NLP) is at the forefront of great advances in contemporary AI, and it is arguably one of the most challenging areas of the field. At the same time, with the steady growth of quantum hardware and notable improvements towards implementations of quantum algorithms, we are approaching an era when quantum computers perform tasks that cannot be done on classical computers with a reasonable amount of resources. This provides a new range of opportunities for AI, and for NLP specifically. Earlier work has already demonstrated a potential quantum advantage for NLP in a number of manners: (i) algorithmic speedups for search-related or classification tasks, which are the most dominant tasks within NLP, (ii) exponentially large quantum state spaces allow for accommodating complex linguistic structures, (iii) novel models of meaning employing density matrices naturally model linguistic phenomena such as hyponymy and linguistic ambiguity, among others. In this work, we perform the first implementation of an NLP task on noisy intermediate-scale quantum (NISQ) hardware. Sentences are instantiated as parameterised quantum circuits. We encode word-meanings in quantum states and we explicitly account for grammatical structure, which even in mainstream NLP is not commonplace, by faithfully hard-wiring it as entangling operations. This makes our approach to quantum natural language processing (QNLP) particularly NISQ-friendly. Our novel QNLP model shows concrete promise for scalability as the quality of the quantum hardware improves in the near future.

Subjects: **Quantum Physics (quant-ph)**; Computation and Language (cs.CL)

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Forbes

Cambridge Quantum Makes Quantum Natural Language Processing A Reality

Paul Smith-Goodson Contributor
Moor Insights and Strategy Contributor Group

Oct 13, 2021, 03:16pm EDT

Listen to article 6 minutes

Quantinuum Enhances The World's First Quantum Natural Language Processing Toolkit Making It Even More Powerful

Paul Smith-Goodson Contributor
Moor Insights and Strategy Contributor Group

Apr 12, 2022, 03:02pm EDT

Listen to article 10 minutes

Now YOU just do it!

arXiv > cs > arXiv:2110.04236

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Computer Science > Computation and Language

[Submitted on 8 Oct 2021]

lambeq: An Efficient High-Level Python Library for Quantum NLP

Dimitri Kartsaklis, Ian Fan, Richie Yeung, Anna Pearson, Robin Lorenz, Alexis Toumi, Giovanni de Felice, Konstantinos Meichanetzidis, Stephen Clark, Bob Coecke

We present lambeq, the first high-level Python library for Quantum Natural Language Processing (QNLP). The open-source toolkit offers a detailed hierarchy of modules and classes implementing all stages of a pipeline for converting sentences to string diagrams, tensor networks, and quantum circuits ready to be used on a quantum computer. lambeq supports syntactic parsing, rewriting and simplification of string diagrams, ansatz creation and manipulation, as well as a number of compositional models for preparing quantum-friendly representations of sentences, employing various degrees of syntax sensitivity. We present the generic architecture and describe the most important modules in detail, demonstrating the usage with illustrative examples. Further, we test the toolkit in practice by using it to perform a number of experiments on simple NLP tasks, implementing both classical and quantum pipelines.

Subjects: **Computation and Language (cs.CL)**; Artificial Intelligence (cs.AI); Quantum Physics (quant-ph)

And you do it even bigger!

 

arXiv > cs > arXiv:2209.03152

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Computer Science > Computation and Language

[Submitted on 7 Sep 2022]

A multiclass Q-NLP sentiment analysis experiment using DisCoCat

Victor Martinez, Guilhaume Leroy-Meline

Sentiment analysis is a branch of Natural Language Processing (NLP) which goal is to assign sentiments or emotions to particular sentences or words. Performing this task is particularly useful for companies wishing to take into account customer feedback through chatbots or verbatim. This has been done extensively in the literature using various approaches, ranging from simple models to deep transformer neural networks. In this paper, we will tackle sentiment analysis in the Noisy Intermediate Scale Computing (NISQ) era, using the DisCoCat model of language. We will first present the basics of quantum computing and the DisCoCat model. This will enable us to define a general framework to perform NLP tasks on a quantum computer. We will then extend the two-class classification that was performed by Lorenz et al. (2021) to a four-class sentiment analysis experiment on a much larger dataset, showing the scalability of such a framework.

Subjects: **Computation and Language (cs.CL)**; Emerging Technologies (cs.ET)

And you generate!

Quantum Natural Language Generation on Near-Term Devices

Amin Karamlou*
IBM Quantum
University of Oxford

Marcel Pfaffhauser
IBM Quantum

James Wootton
IBM Quantum

Abstract

The emergence of noisy medium-scale quantum devices has led to proof-of-concept applications for quantum computing in various domains. Examples include Natural Language Processing (NLP) where sentence classifica-

perform perfect operations (Preskill, 2018). Despite their shortcomings, these devices represent a significant milestone for quantum computing. This is because unlike their smaller predecessors they cannot be simulated efficiently on classical hardware. Hence, it is possible that near-term quantum

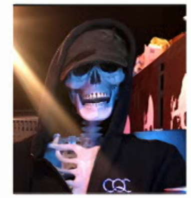
Qiskit

10 min read · Draft · Listen

An introduction to Quantum Natural Language Processing

Today we're going to talk about how you can use IBM quantum computers for generating natural language and music. We've made the python notebook for generating the pieces of music used as examples in this blog post available on our GitHub repository. Feel free to use them for generating your own pieces, it can be quite fun! We'll keep things pretty high level but you can check out our paper available here for more details. You can also watch a recording of our talk at the 2022 Quantum Natural Language Processing conference here.

Quanthoven paper

arXiv > quant-ph > arXiv:2111.06741

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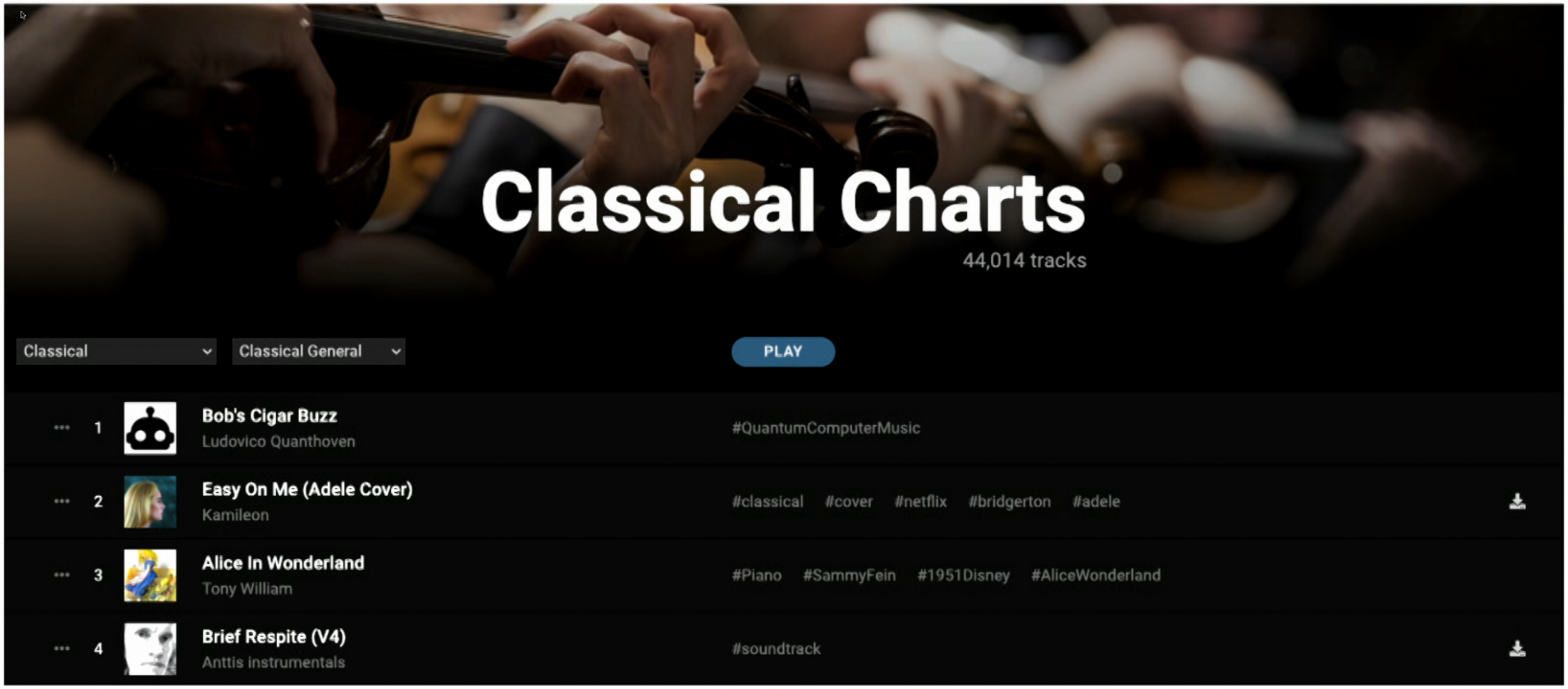
Quantum Physics

[Submitted on 10 Nov 2021 (v1), last revised 9 Dec 2021 (this version, v2)]

A Quantum Natural Language Processing Approach to Musical Intelligence

Eduardo Reck Miranda, Richie Yeung, Anna Pearson, Konstantinos Meichanetzidis, Bob Coecke

There has been tremendous progress in Artificial Intelligence (AI) for music, in particular for musical composition and access to large databases for commercialisation through the Internet. We are interested in further advancing this field, focusing on composition. In contrast to current black-box AI methods, we are championing an interpretable compositional outlook on generative music systems. In particular, we are importing methods from the Distributional Compositional Categorical (DisCoCat) modelling framework for Natural Language Processing (NLP), motivated by musical grammars. Quantum computing is a nascent technology, which is very likely to impact the music industry in time to come. Thus, we are pioneering a Quantum Natural Language Processing (QNLP) approach to develop a new generation of intelligent musical systems. This work follows from previous experimental implementations of DisCoCat linguistic models on quantum hardware. In this chapter, we present Quanthoven, the first proof-of-concept ever built, which (a) demonstrates that it is possible to program a quantum computer to learn to classify music that conveys different meanings and (b) illustrates how such a capability might be leveraged to develop a system to compose meaningful pieces of music. After a discussion about our current understanding of music as a communication medium and its relationship to natural language, the chapter focuses on the techniques developed to (a) encode musical compositions as quantum circuits, and (b) design a quantum classifier. The chapter ends with demonstrations of compositions created with the system.


Classical Charts
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Classical
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PLAY
1
Bob's Cigar Buzz
Ludovico Quanthoven
#QuantumComputerMusic
2
Easy On Me (Adele Cover)
Kamileon
#classical #cover #netflix #bridgerton #adele
3
Alice In Wonderland
Tony William
#Piano #SammyFein #1951Disney #AliceWonderland
4
Brief Respite (V4)
Anttis instrumentals
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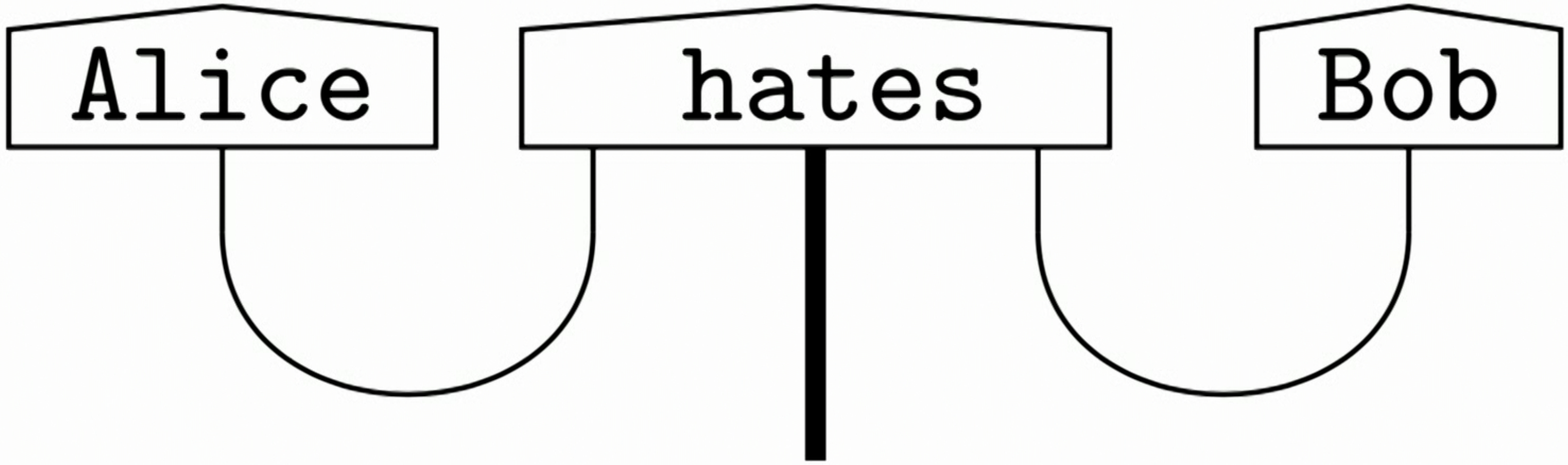
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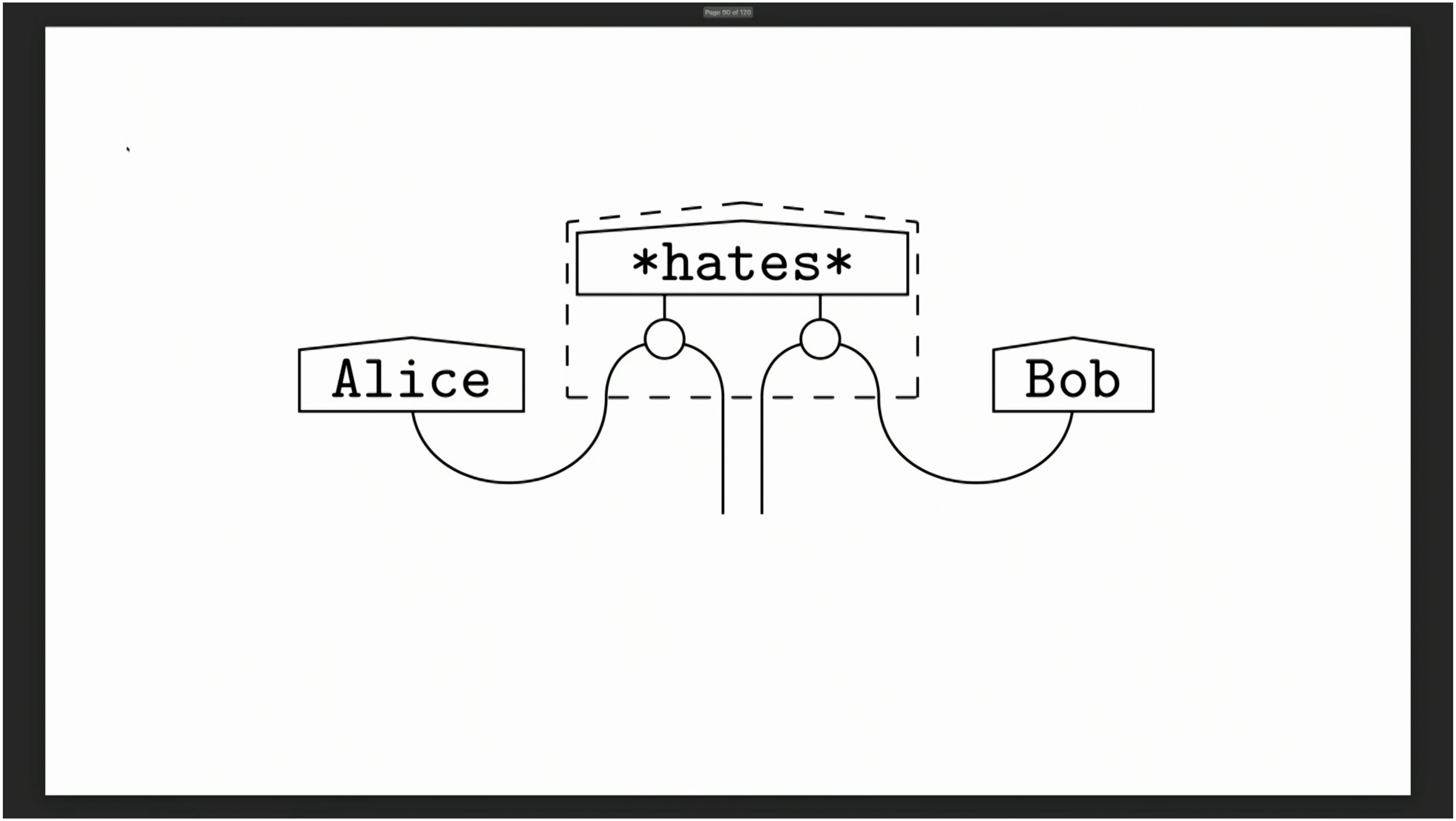
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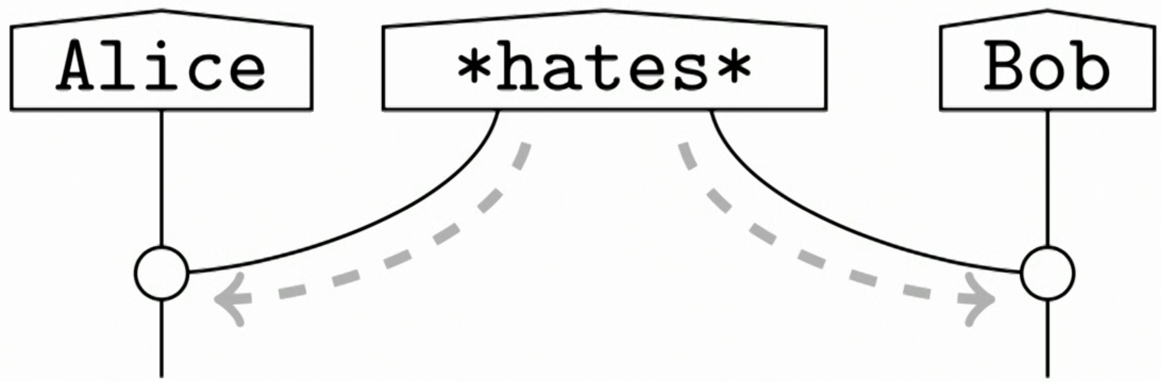
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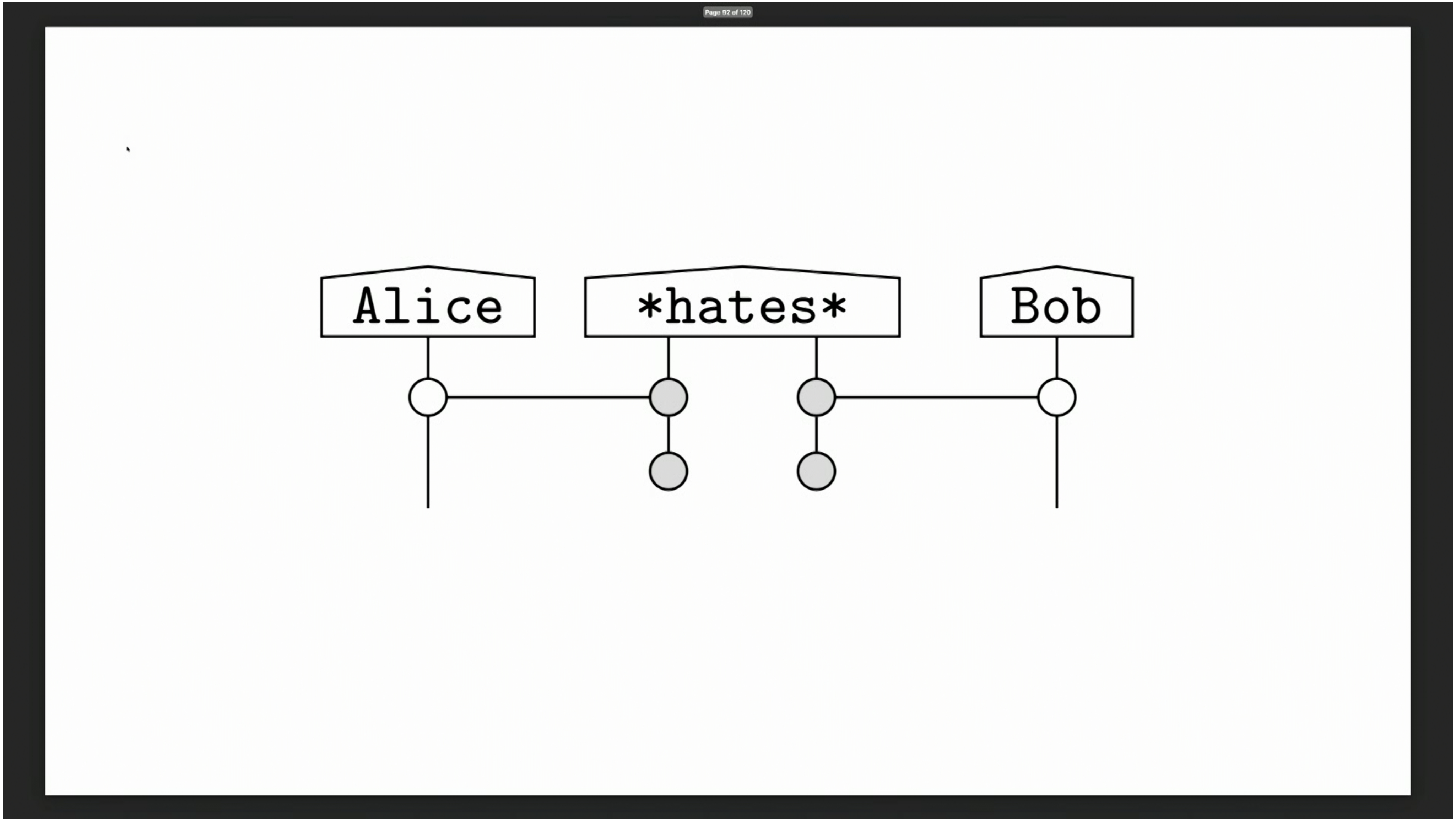
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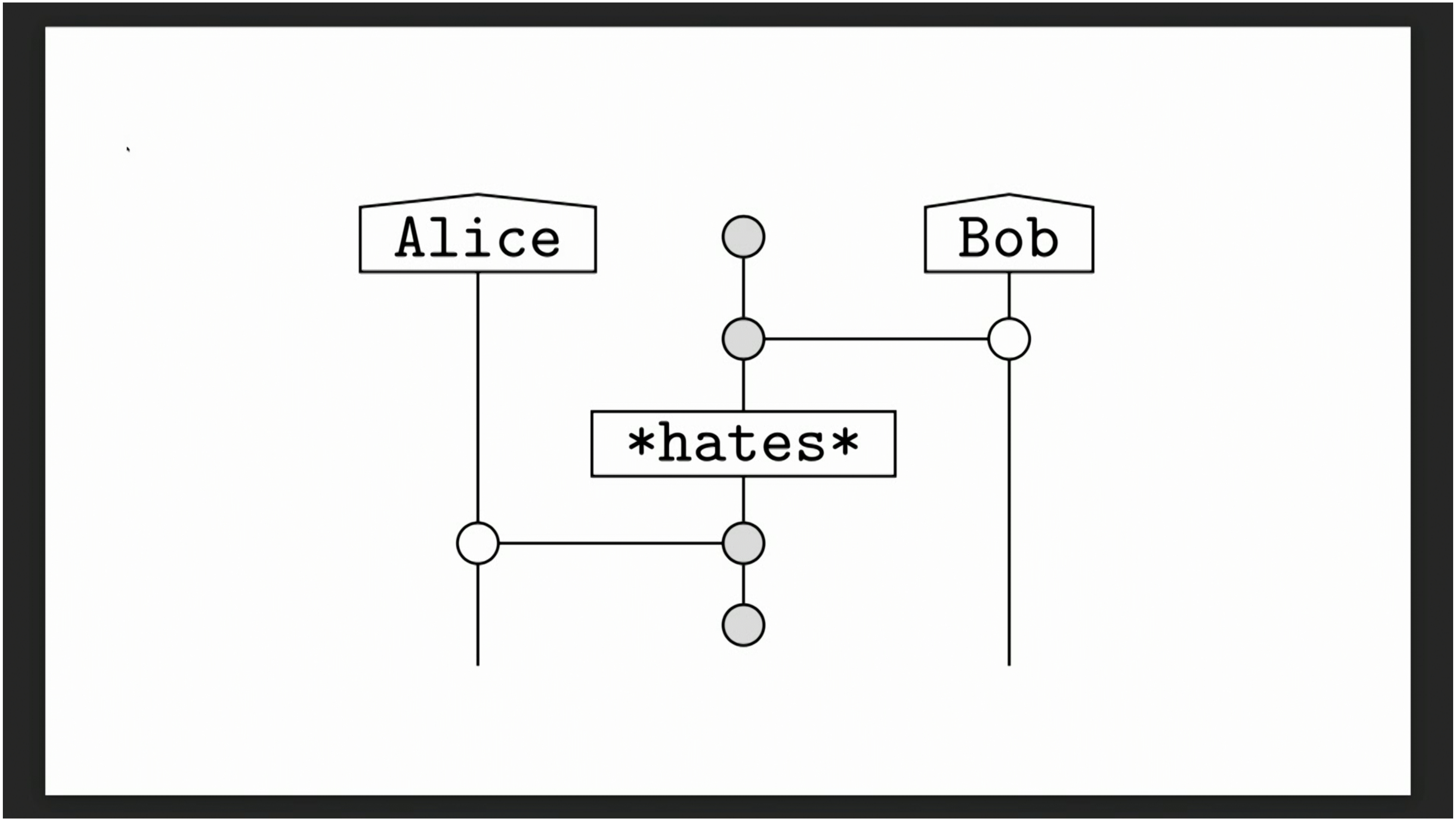
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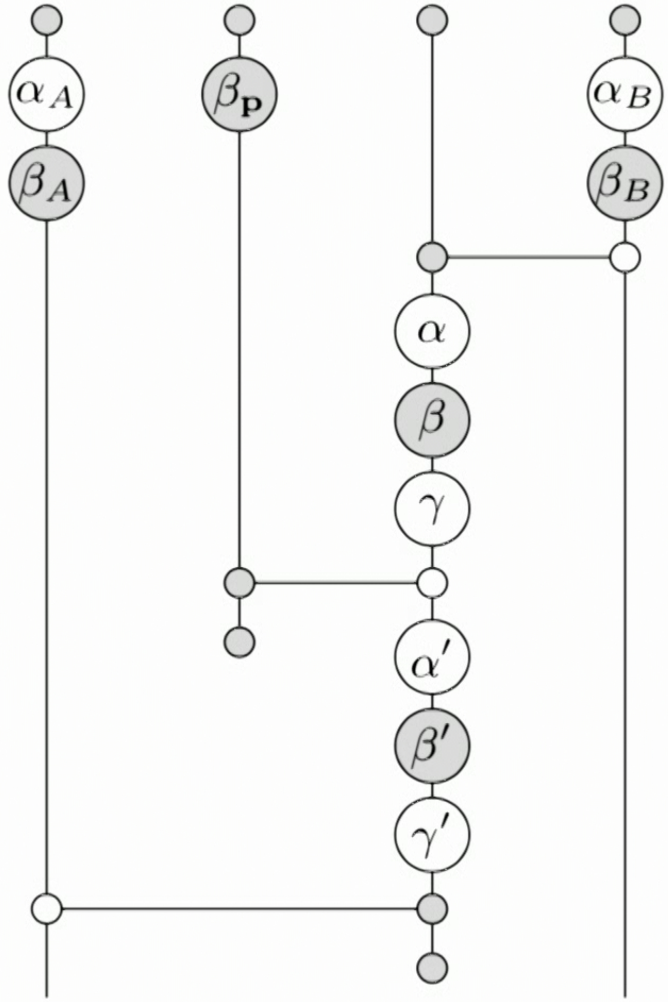
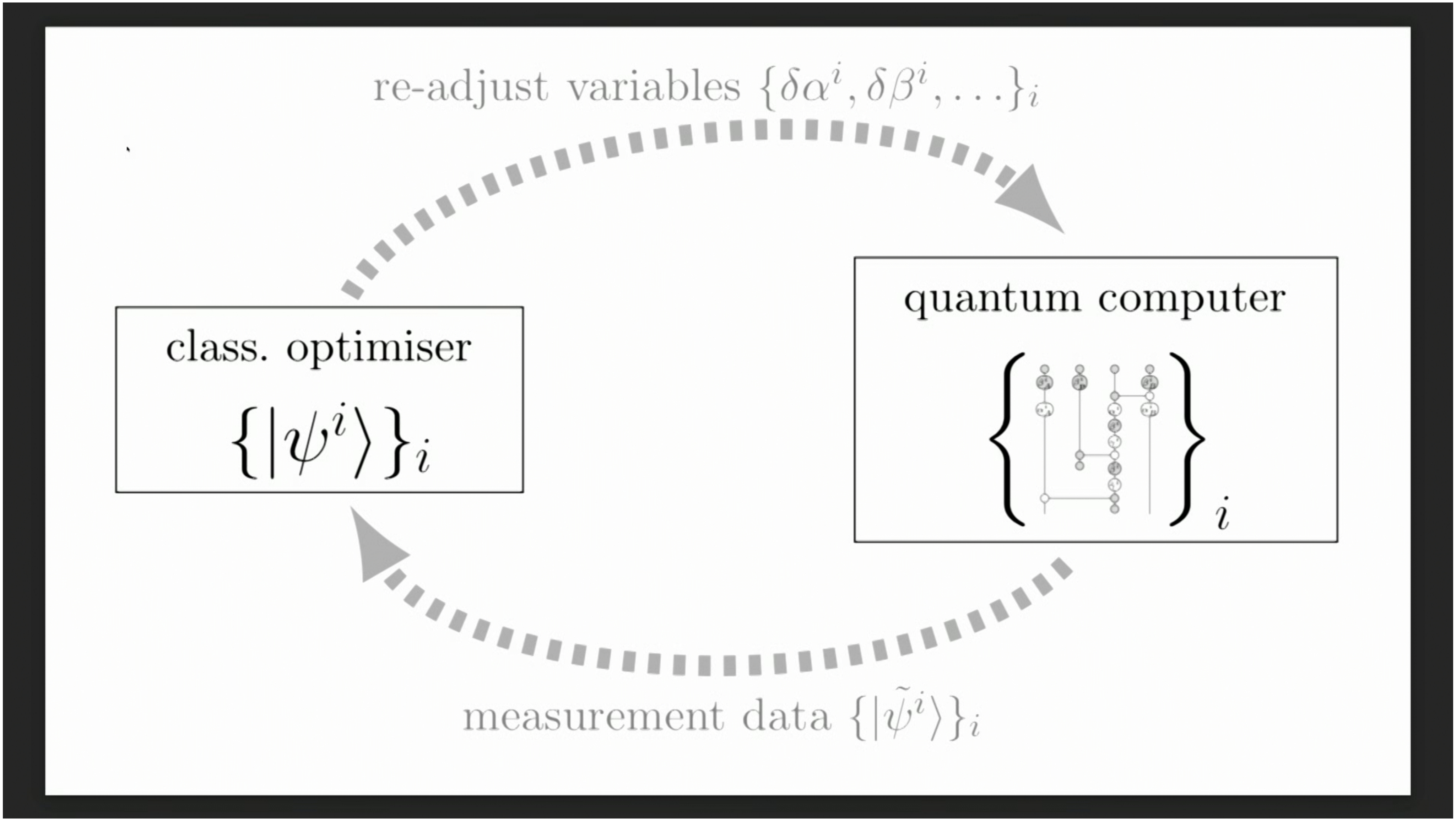


α_A
$\beta_{\mathbf{P}}$
α_B
β_A
β_B
α
β
γ
α'
β'
γ'


re-adjust variables $\{\delta\alpha^i, \delta\beta^i, \ldots\}_i$
class. optimiser
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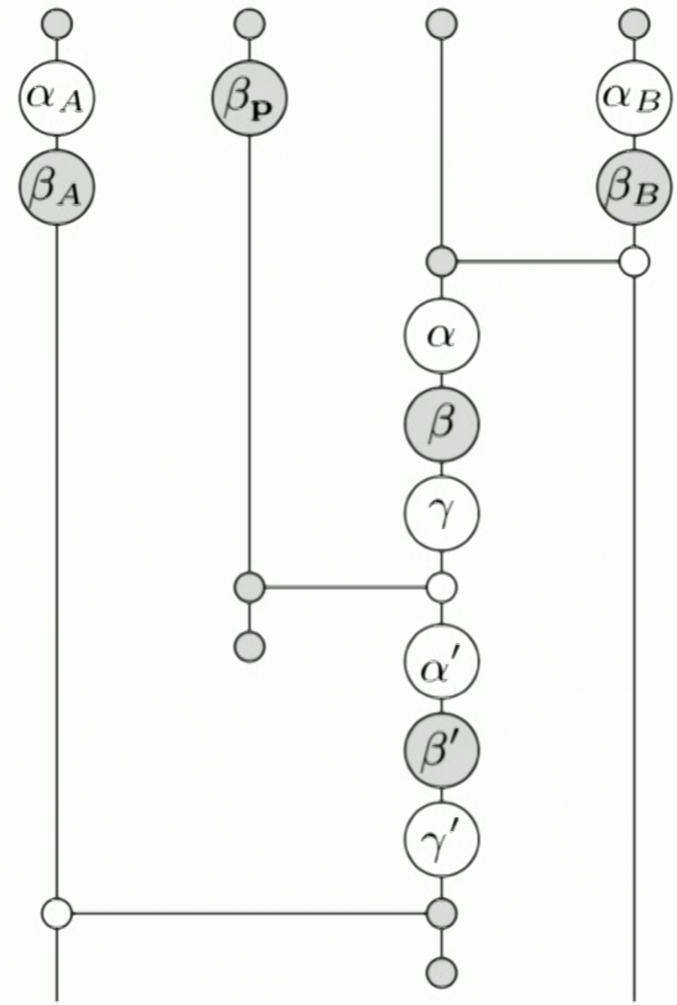
quantum computer
i
measurement data $\{|\tilde{\psi}^i\rangle\}_i$

text circuits: a new theory of language



α_A
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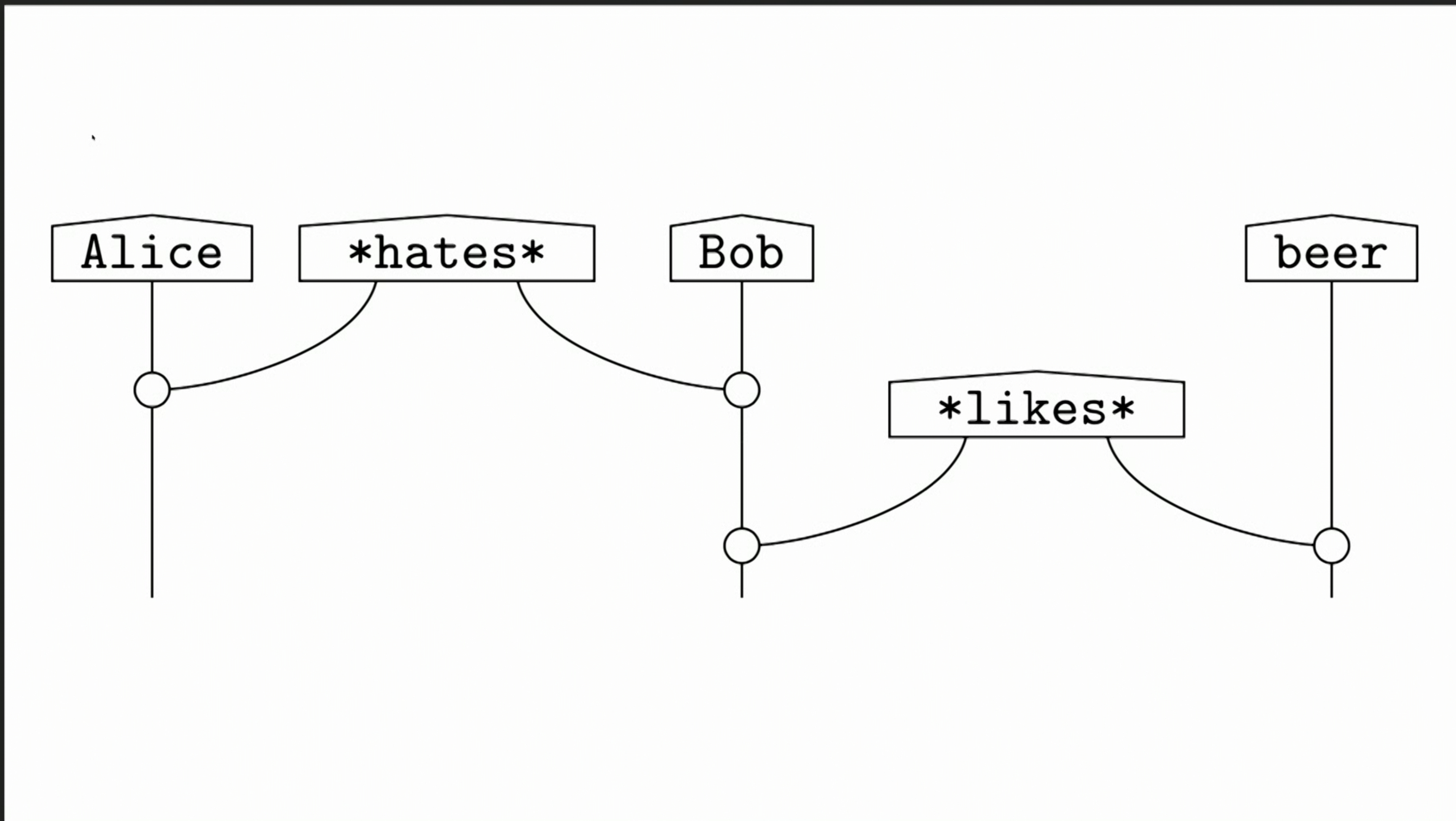
text circuits: a new theory of language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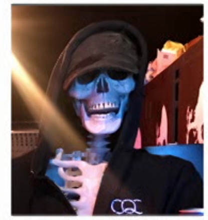

arXiv > cs > arXiv:2301.10595

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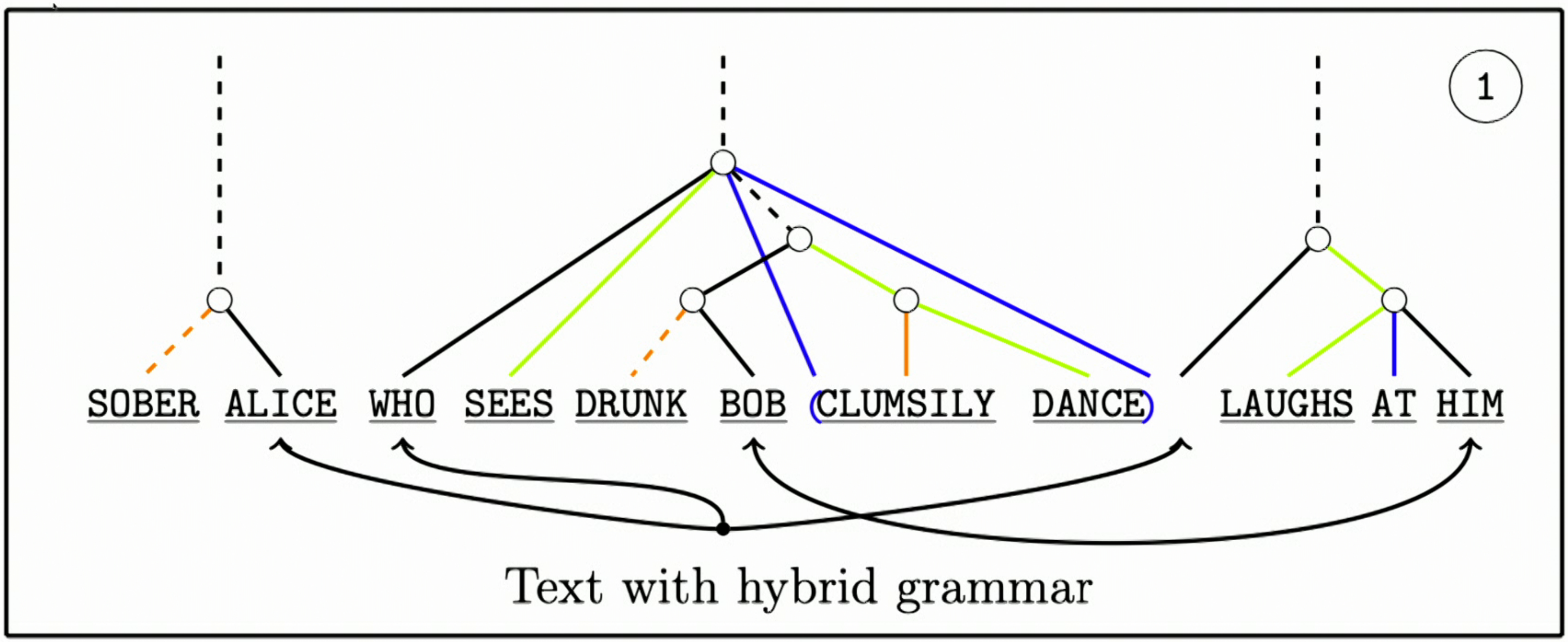
Computer Science > Computation and Language

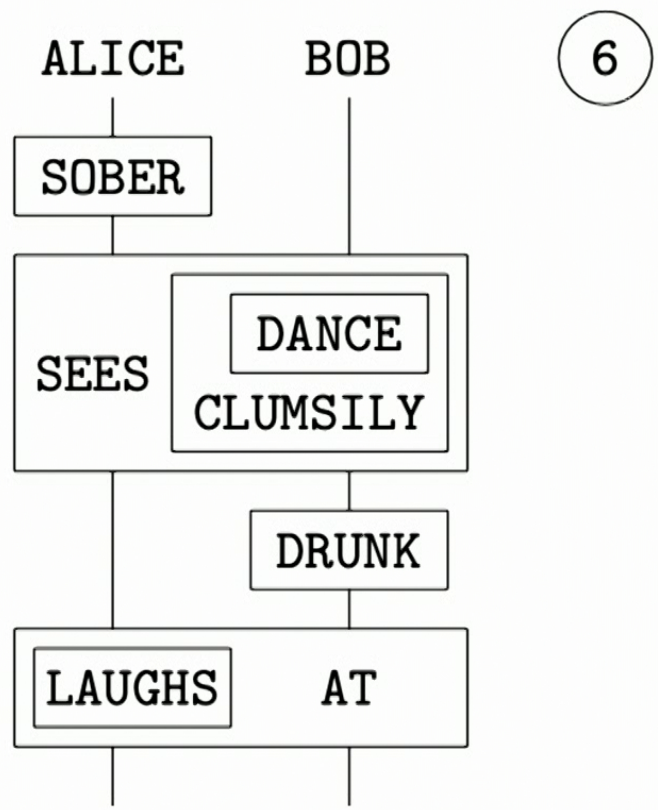
[Submitted on 25 Jan 2023]

Distilling Text into Circuits

Vincent Wang-Mascianica, Jonathon Liu, Bob Coecke

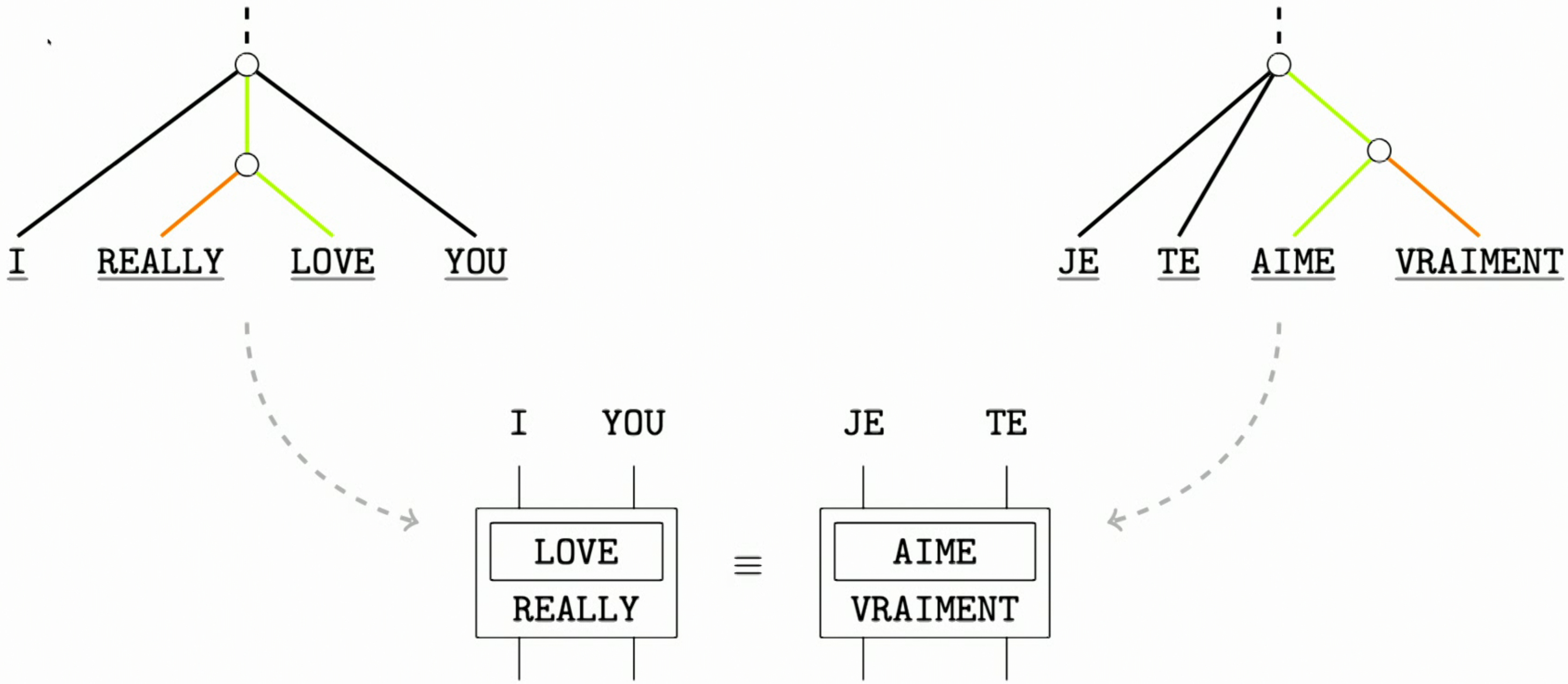
This paper concerns the structure of meanings within natural language. Earlier, a framework named DisCoCirc was sketched that (1) is compositional and distributional (a.k.a. vectorial); (2) applies to general text; (3) captures linguistic `connections' between meanings (cf. grammar) (4) updates word meanings as text progresses; (5) structures sentence types; (6) accommodates ambiguity. Here, we realise DisCoCirc for a substantial fragment of English.
When passing to DisCoCirc's text circuits, some `grammatical bureaucracy' is eliminated, that is, DisCoCirc displays a significant degree of (7) inter- and intra-language independence. That is, e.g., independence from word-order conventions that differ across languages, and independence from choices like many short sentences vs. few long sentences. This inter-language independence means our text circuits should carry over to other languages, unlike the language-specific typings of categorial grammars. Hence, text circuits are a lean structure for the `actual substance of text', that is, the inner-workings of meanings within text across several layers of expressiveness (cf. words, sentences, text), and may capture that what is truly universal beneath grammar. The elimination of grammatical bureaucracy also explains why DisCoCirc: (8) applies beyond language, e.g. to spatial, visual and other cognitive modes. While humans could not verbally communicate in terms of text circuits, machines can.
We first define a `hybrid grammar' for a fragment of English, i.e. a purpose-built, minimal grammatical formalism needed to obtain text circuits. We then detail a translation process such that all text generated by this grammar yields a text circuit. Conversely, for any text circuit obtained by freely composing the generators, there exists a text (with hybrid grammar) that gives rise to it. Hence: (9) text circuits are generative for text.


1
SOBER ALICE WHO SEES DRUNK BOB (CLUMSILY DANCE) LAUGHS AT HIM
Text with hybrid grammar



...to get a circuit

Different languages become the same!

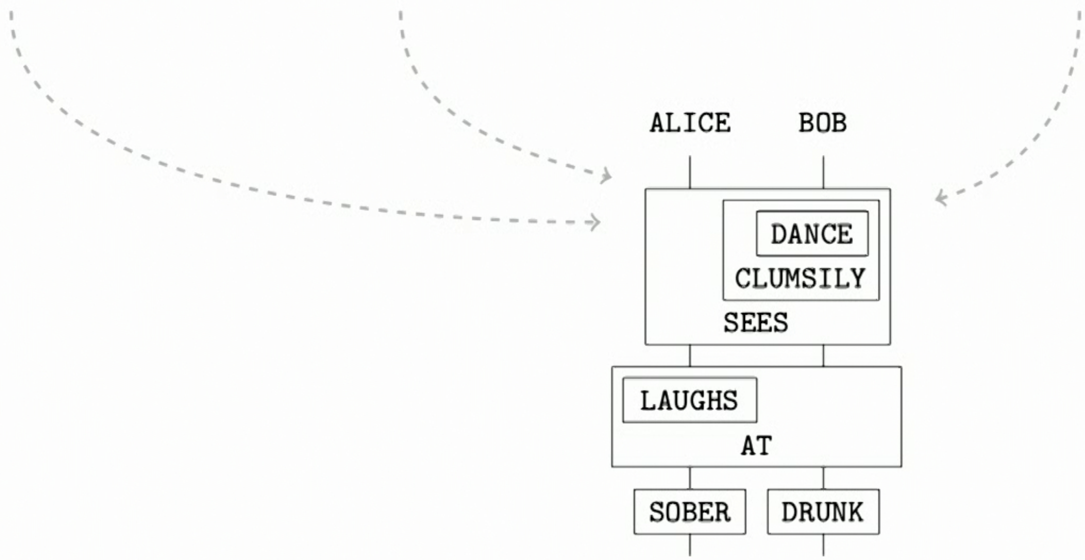


Different styles become the same!

SOBER ALICE WHO
SEES DRUNK BOB
CLUMSILY DANCE
LAUGHS AT HIM.

ALICE SEES BOB DANCE CLUMSILY.
ALICE LAUGHS AT BOB.
BOB IS DRUNK.
ALICE IS SOBER.

ALICE VOIT QUE BOB DANSER MALADROITEMENT.
ALICE SE MOQUE DE BOB.
ALICE EST SOBRE.
BOB EST IVRE.



Different styles become the same!

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CLUMSILY DANCE
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ALICE SE MOQUE DE BOB.
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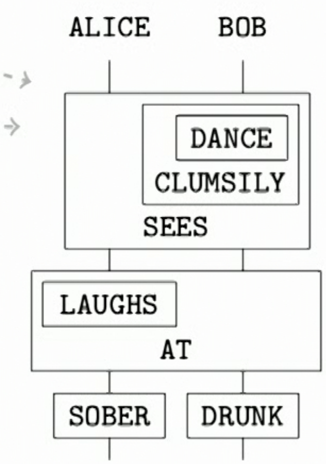
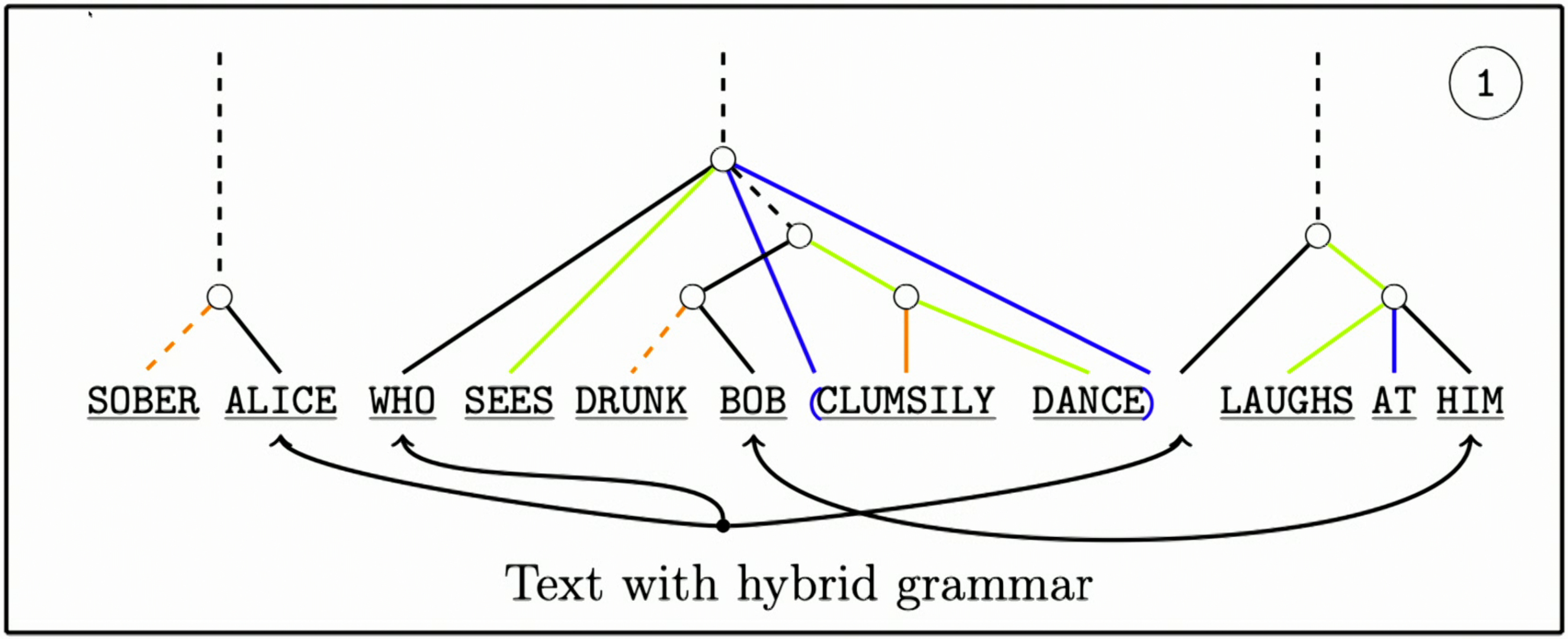
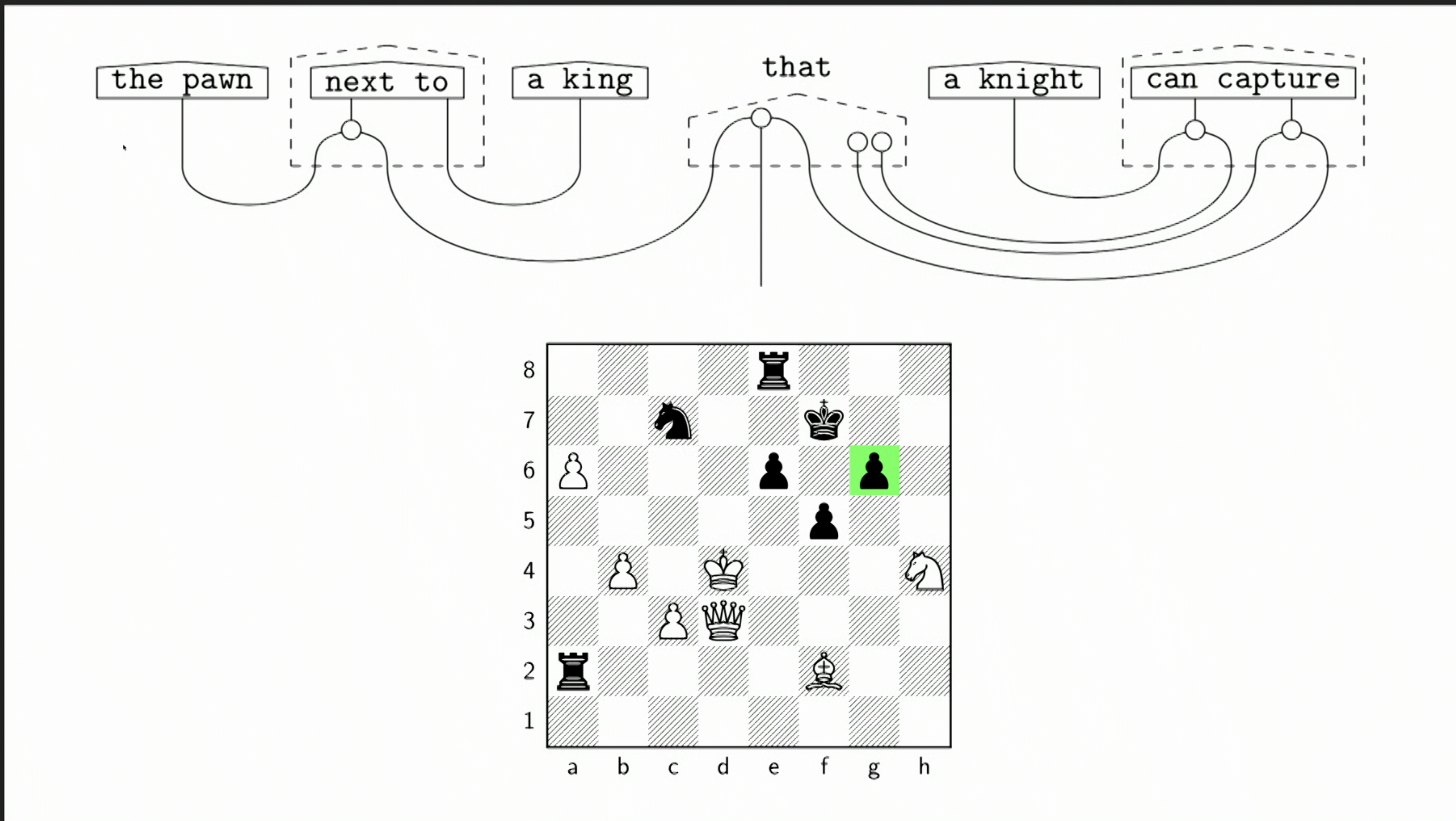



1
SOBER ALICE WHO SEES DRUNK BOB (CLUMSILY DANCE) LAUGHS AT HIM
Text with hybrid grammar



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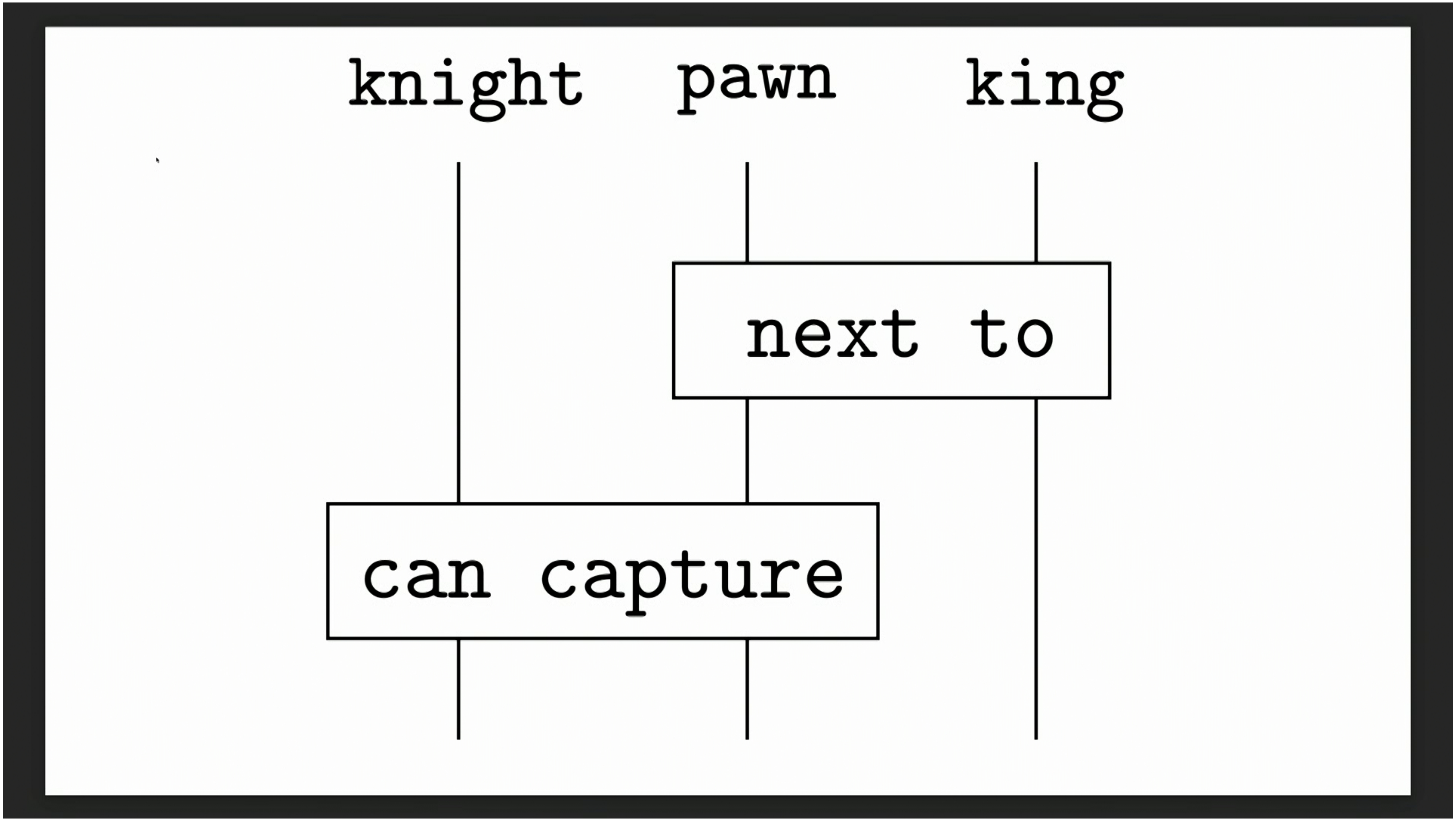
knight
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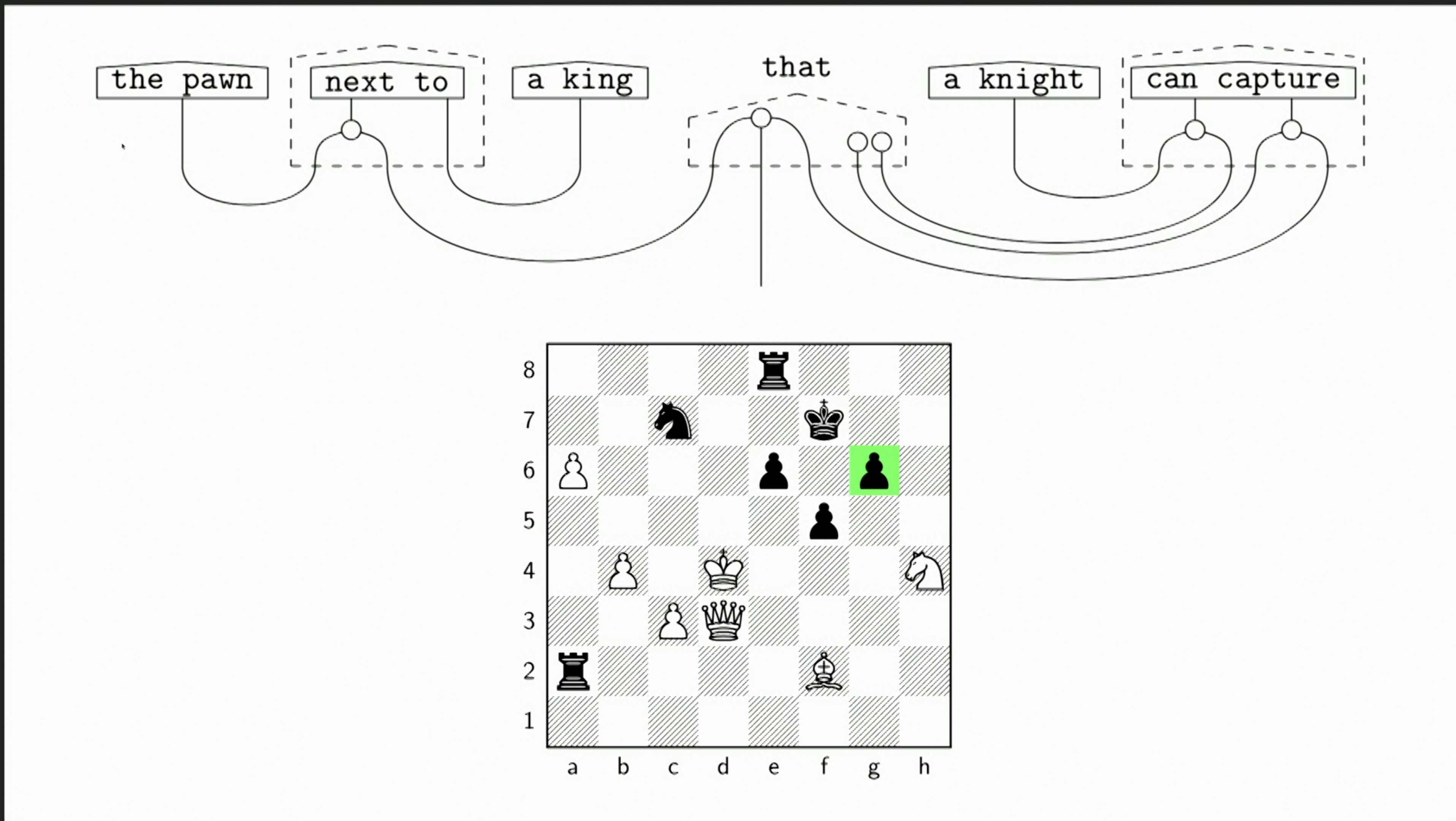
king
next to
can capture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next to
a king
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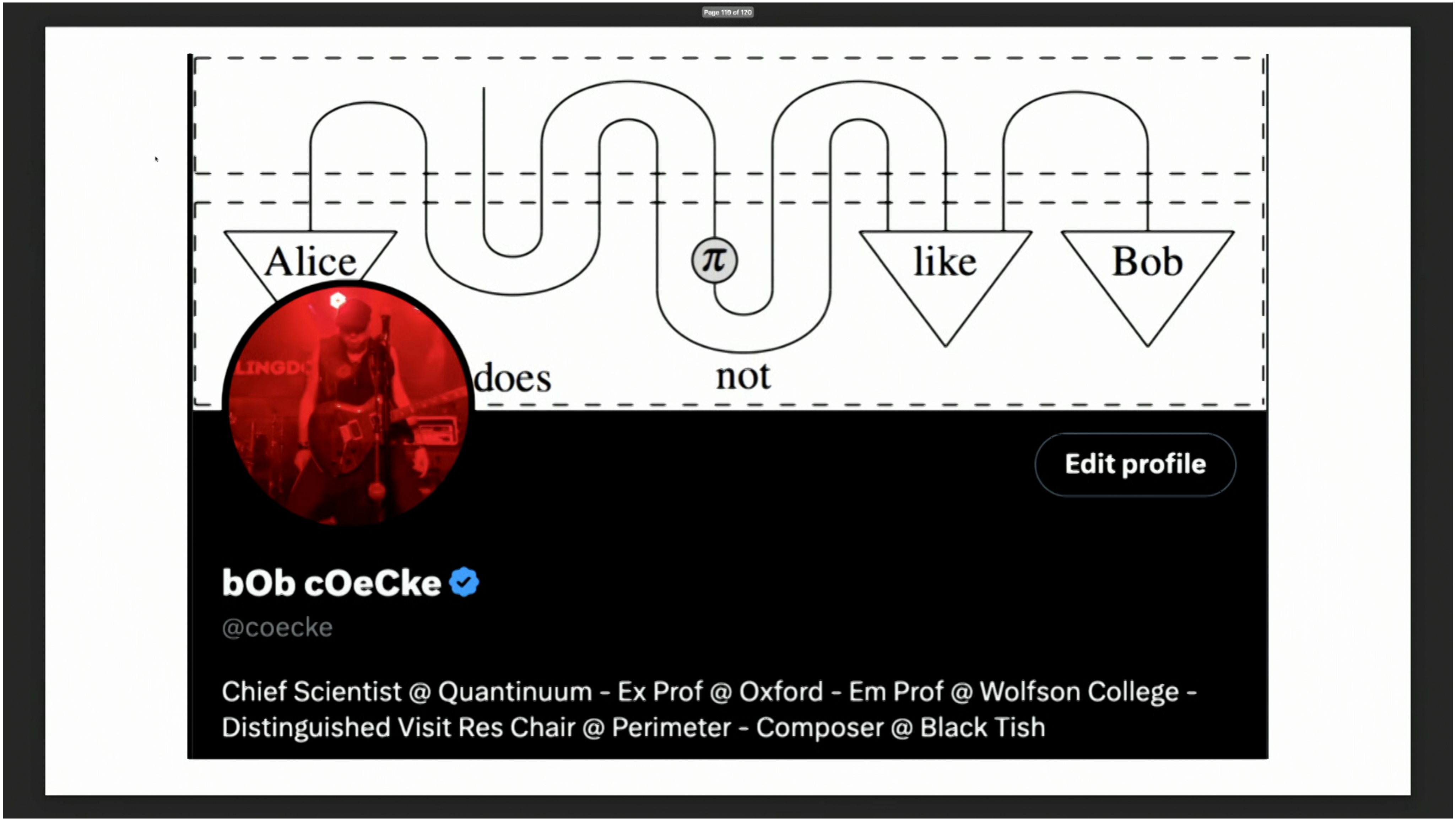
Page 119 of 120
Alice
does
π
not
like
Bob
Edit profile
bOb cOeCke
@coecke
Chief Scientist @ Quantinuum - Ex Prof @ Oxford - Em Prof @ Wolfson College -
Distinguished Visit Res Chair @ Perimeter - Composer @ Black Tish


BLACK TISH
VIRAL APOCALYPSE
OXFORD, 2020-2022
BLACK TISH
1 - NEW NEW
2 - OLD
3 - NEW
4 - SQUISHY
5 - MUSIQUE CONCRETE
6 - SQUISHY SQUISHY
7 - B13 DIGEST
BLINDSIGHT RECORDS