From quantum picturalism to interpretable quantum AI

Bob Coecke

Chief Scientist
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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

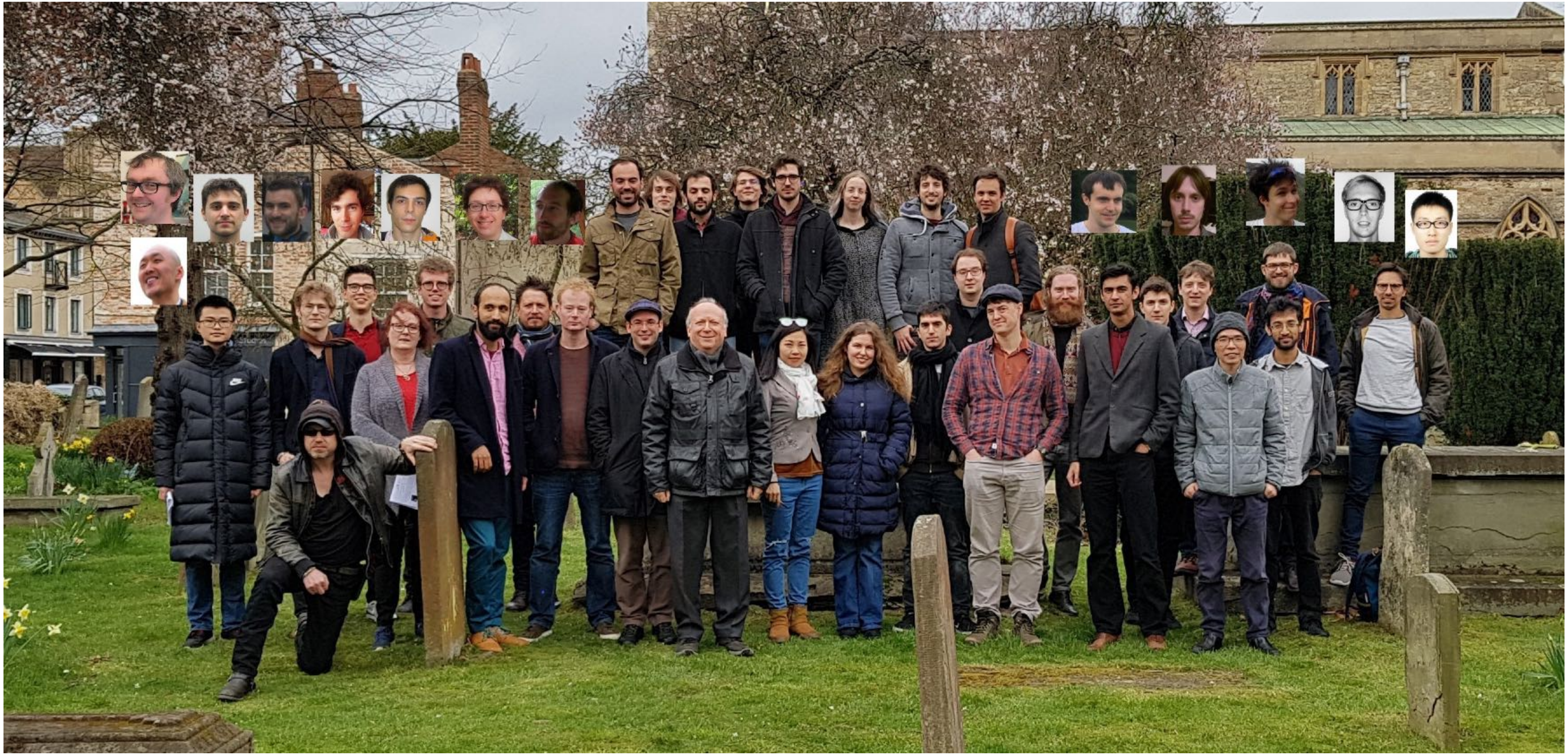
Professor of Quantum Foundations, Logics and Structures

Fellow, Wolfson College

Leaving date: 31st December 2020

2007-2020

Professor @ Oxford University



2020

~~**Professor @ Oxford University**~~

DEPARTMENT OF
COMPUTER
SCIENCE

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BUSINESSWEEKLY

A WORLDWIDE WINDOW TO CAMBRIDGE BUSINESS, INNOVATION & TECHNOLOGY

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

~~Chief Scientist @ Cambridge Quantum~~

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2021-2022

Chief Scientist @ Quantinuum

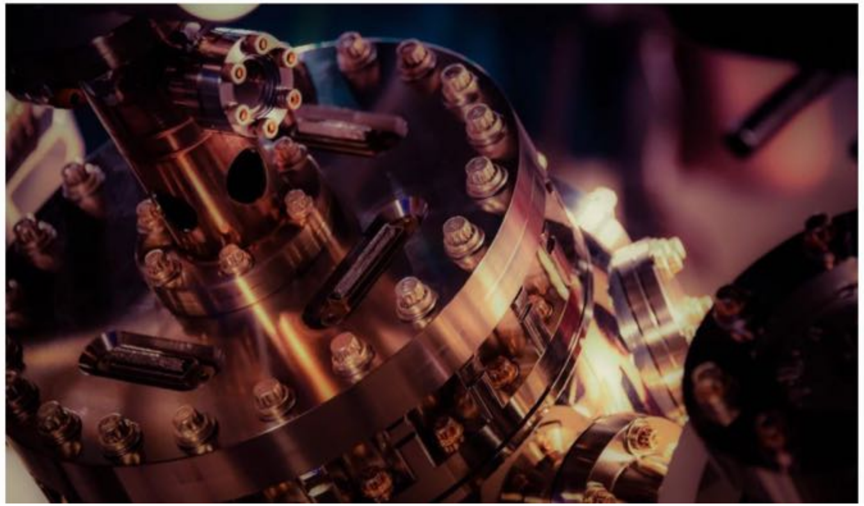
Forbes

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

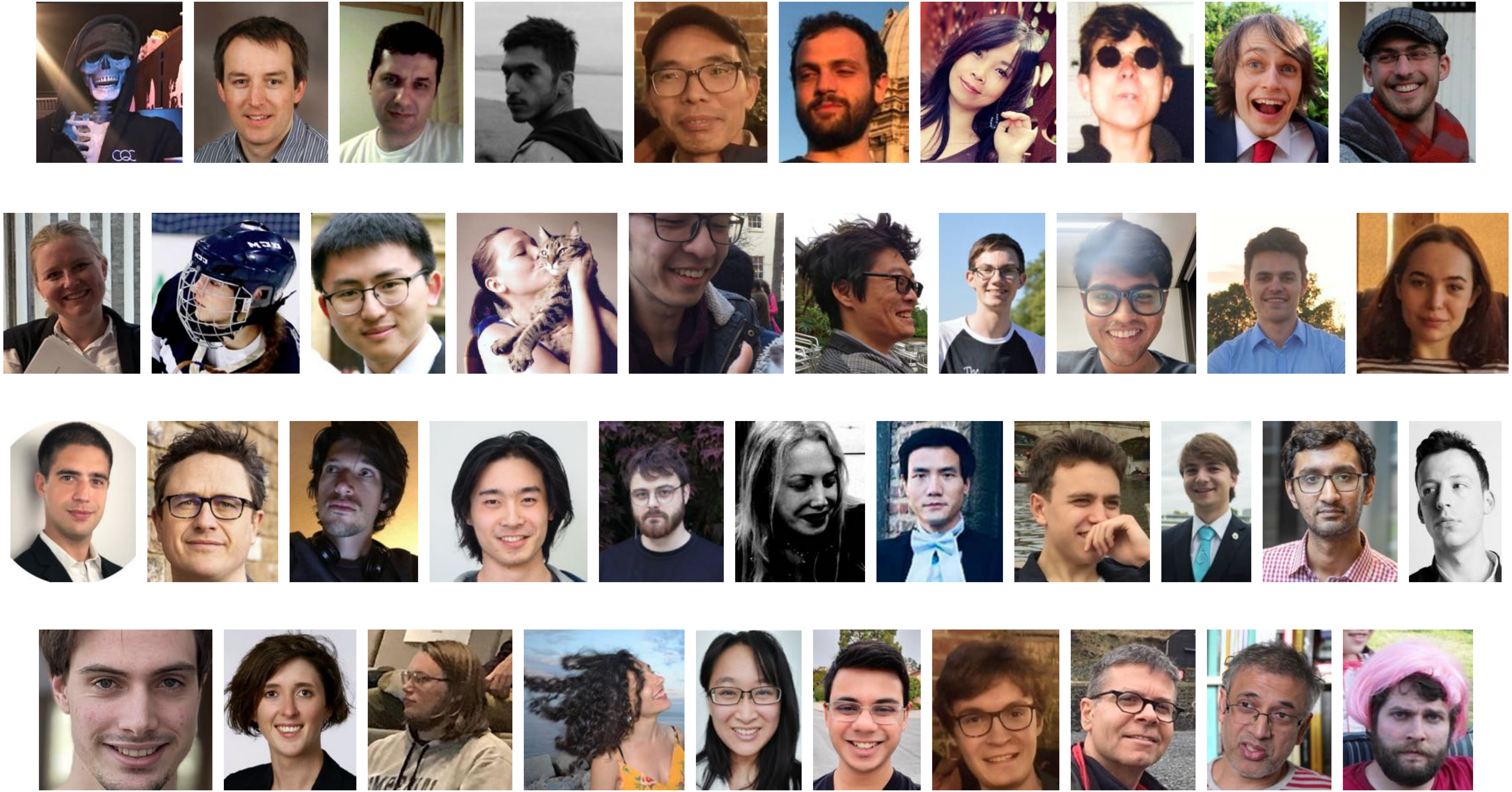
Honeywell Quantum Solutions And Cambridge Quantum Computing Merge With Go-Public In Mind

Paul Smith-Goodson Contributor
Moor Insights and Strategy Contributor Group
Cloud
Analyst-in-residence, Quantum Computing

Listen to article 8 minutes



Quantinuum @ Oxford



our logo

the language of quantum

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

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

Search...

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Quantum Physics

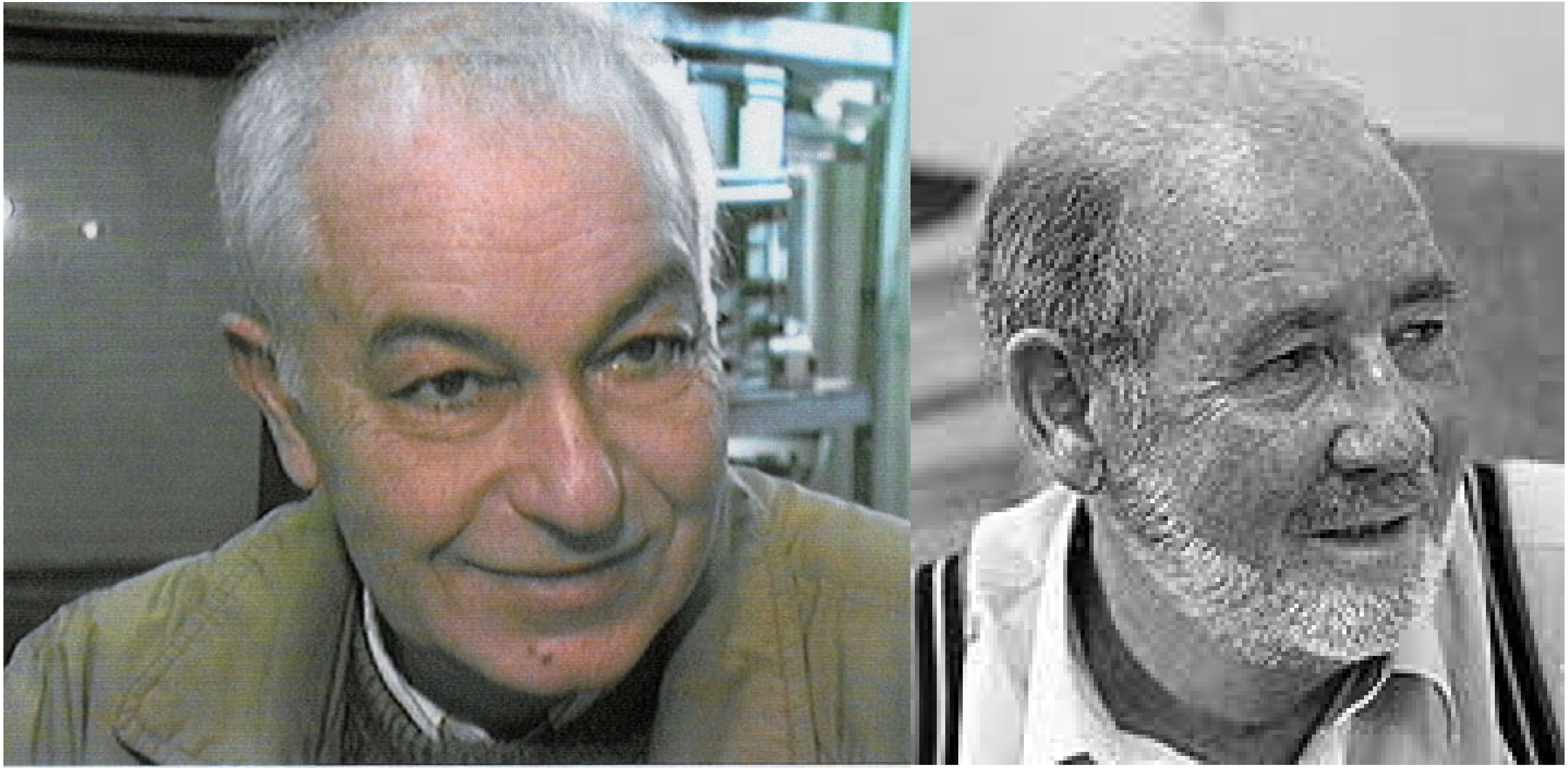
[Submitted on 18 Feb 2004 (v1), last revised 5 Mar 2007 (this version, v5)]

A categorical semantics of quantum protocols

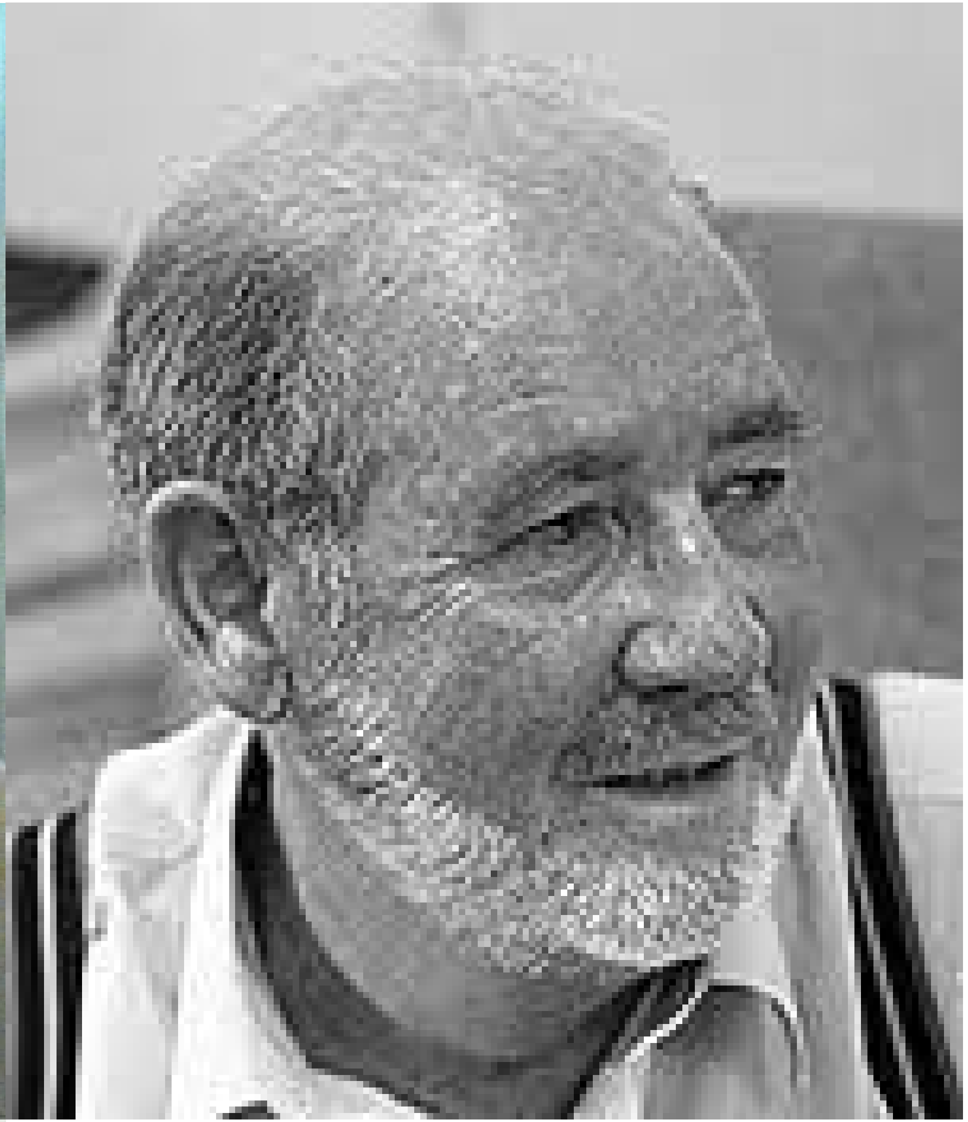
Samson Abramsky, Bob Coecke

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.

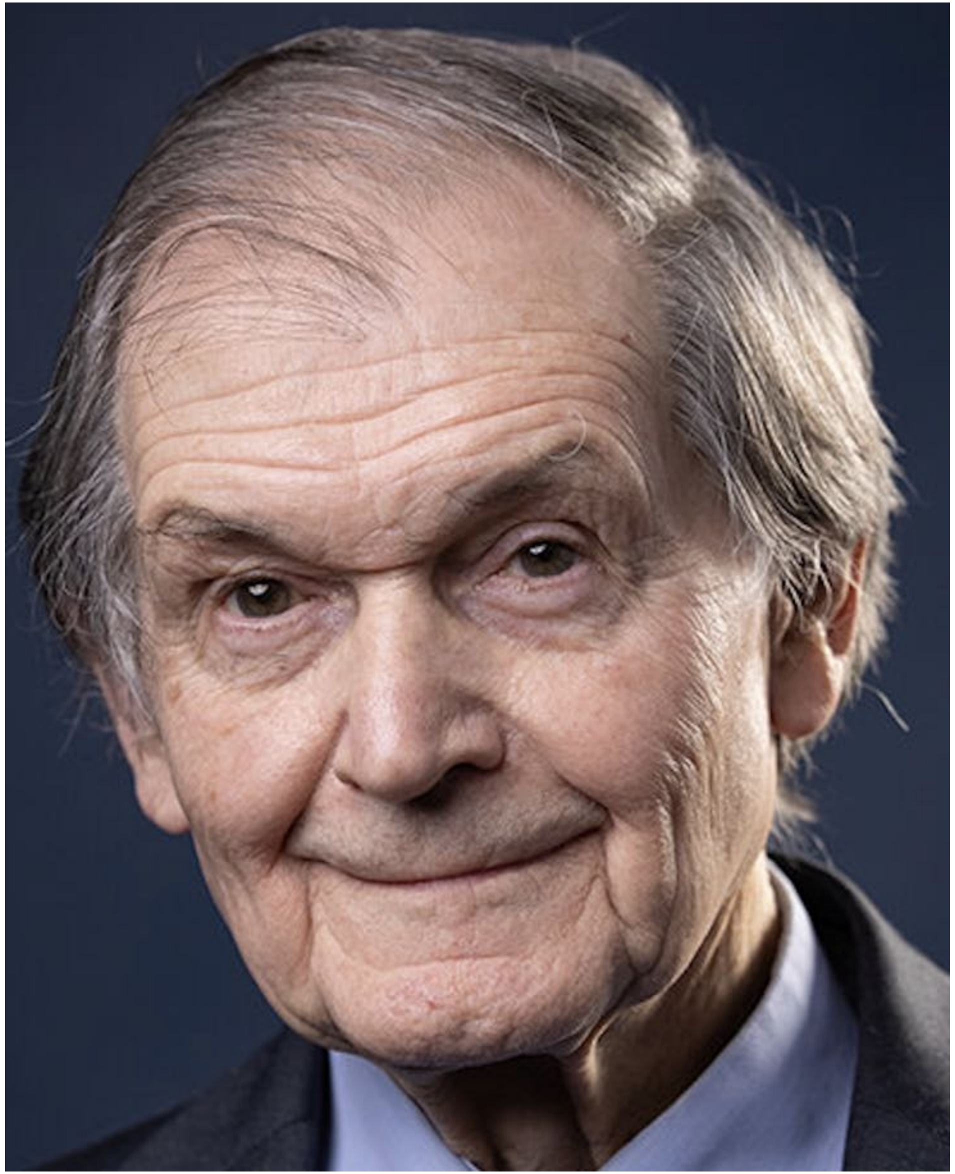
Jean Benabou & Max Kelly



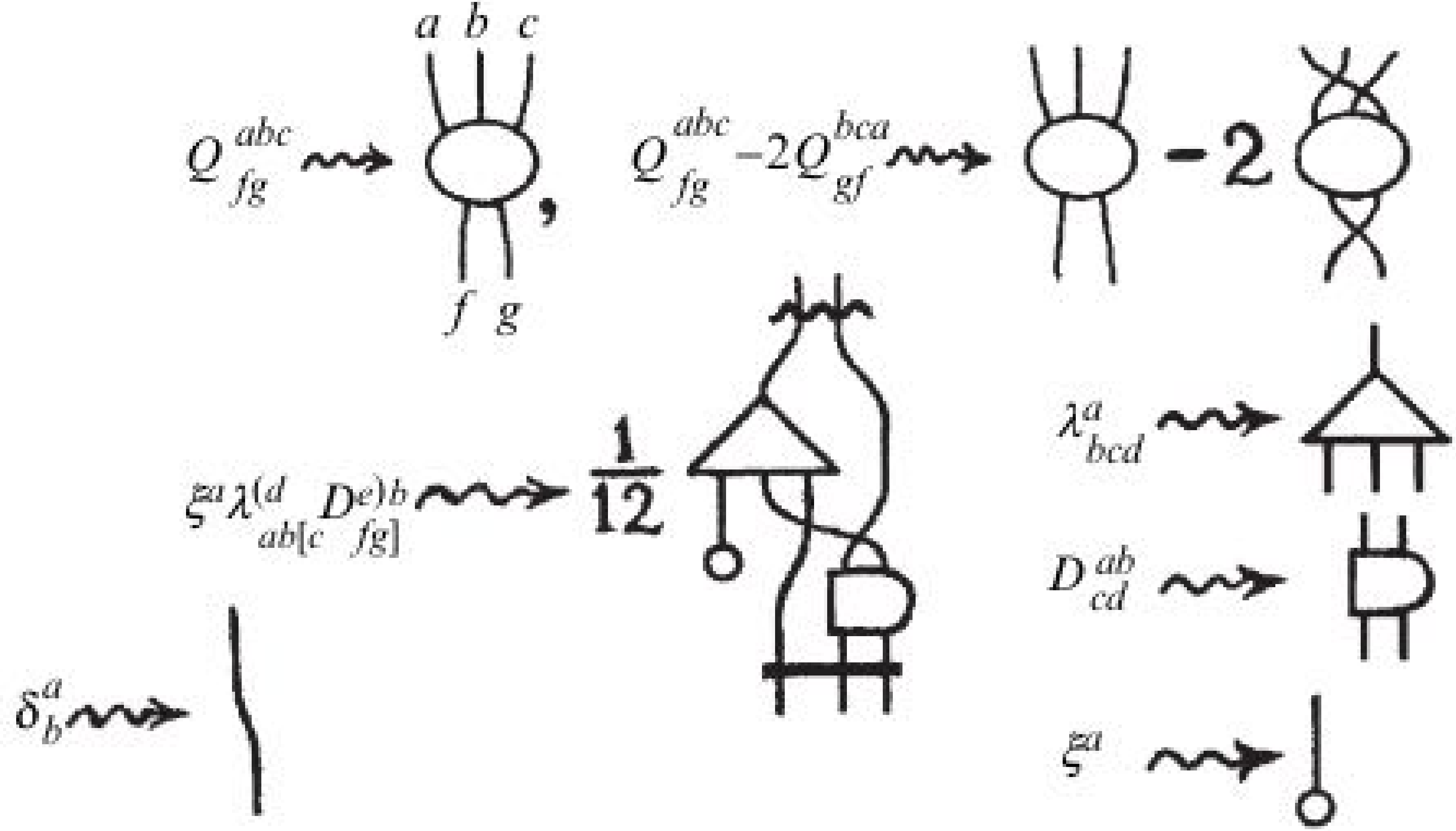
Jean Benabou & Max Kelly (& a dagger)

Roger Penrose



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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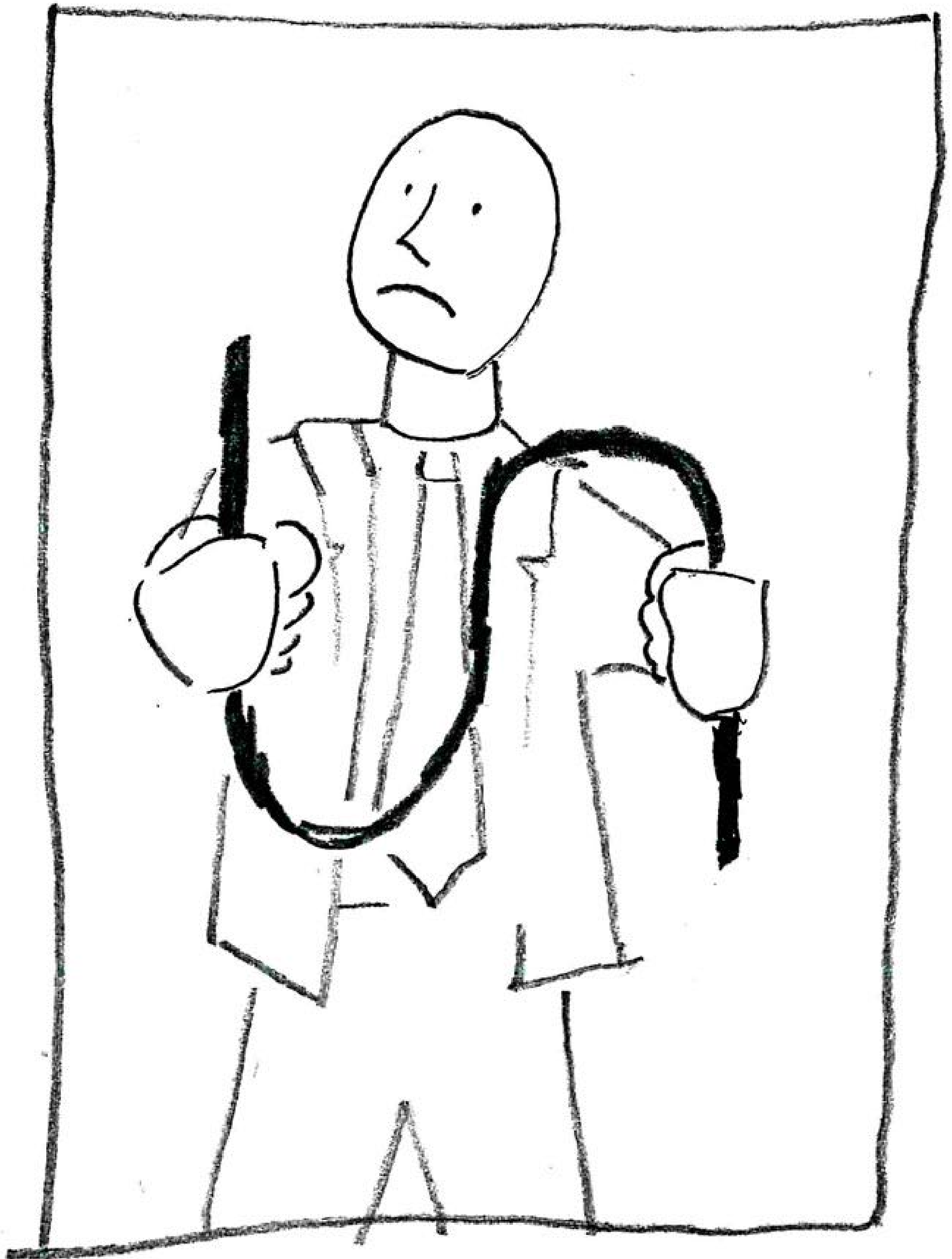
Quantum Physics

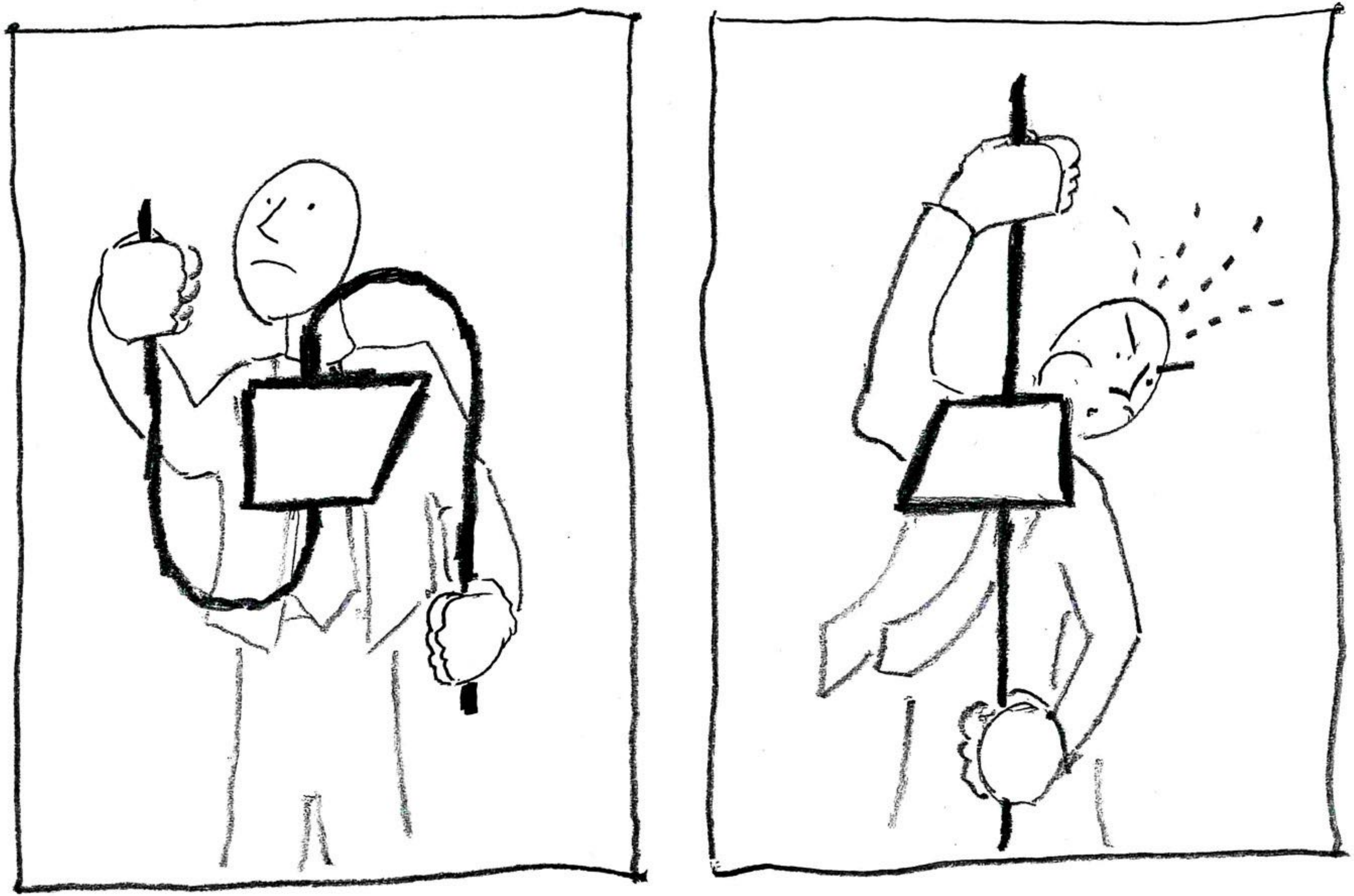
[Submitted on 4 Oct 2005]

Kindergarten Quantum Mechanics

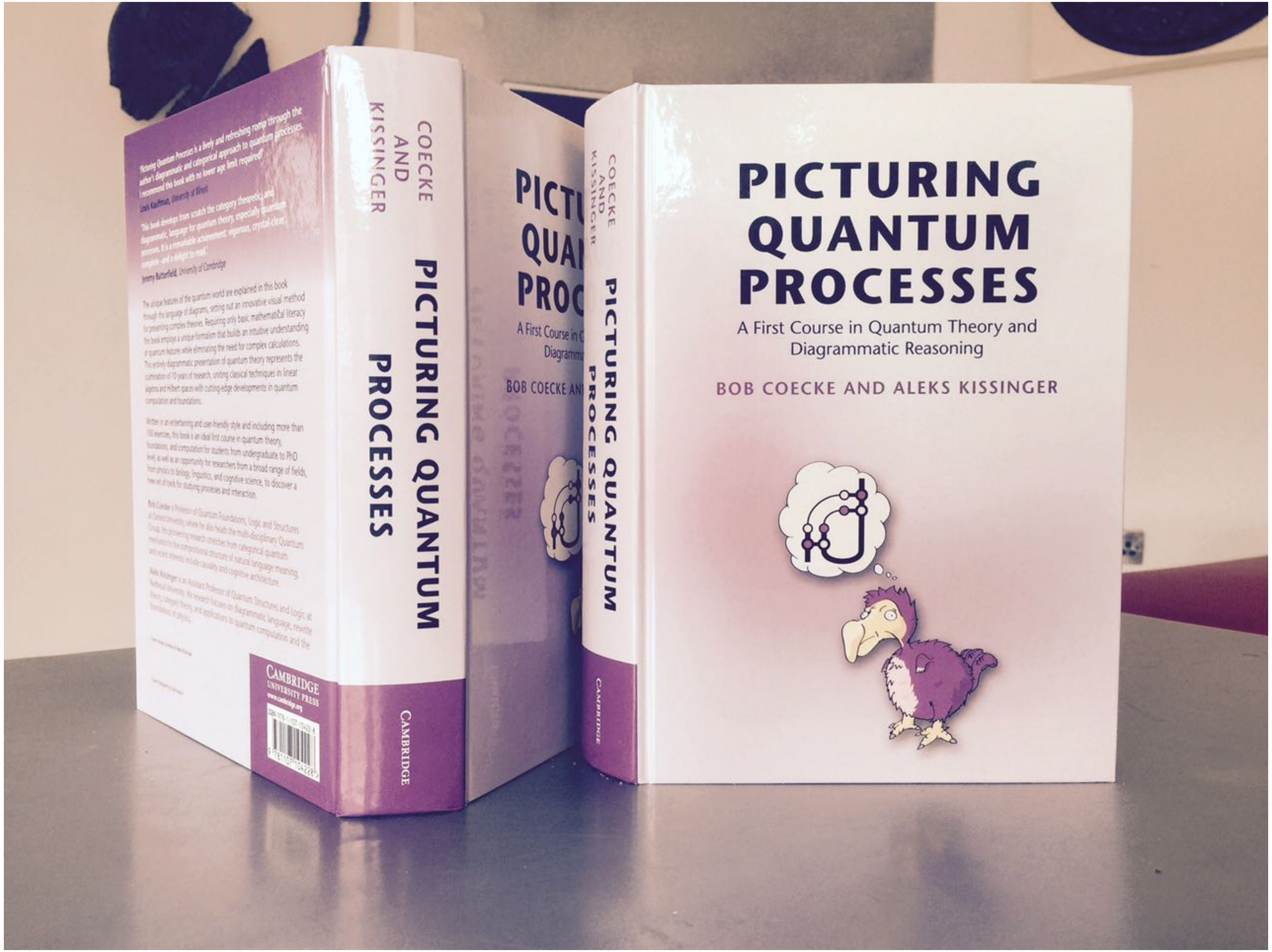
Bob Coecke

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
CAMBRIDGE UNIVERSITY PRESS

...5 years later...

Hello there!
Want to learn some quantum?

Maybe you think you don't know enough maths? Well, that's not a problem! The pictures in this book are a new kind of maths that will teach you all about the quantum world.

From quantum teleportation to the most recent developments in quantum computing, it's all inside. We even cover quantum non-locality, for which the 2022 Nobel Prize was awarded.

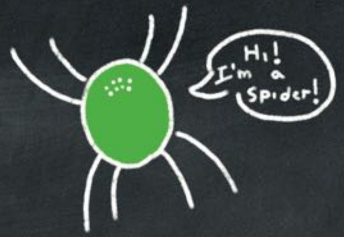
And all of this is done with not-so-scary spiders! Whether you are a young, or not-so-young, amateur; or a specialist, this book is for you.

ISBN 978-1-7392147-1-5

You can also watch all the chapters as videos on Quantinuum's YouTube channel. Enjoy!

QUANTINUUM

QUANTUM IN PICTURES



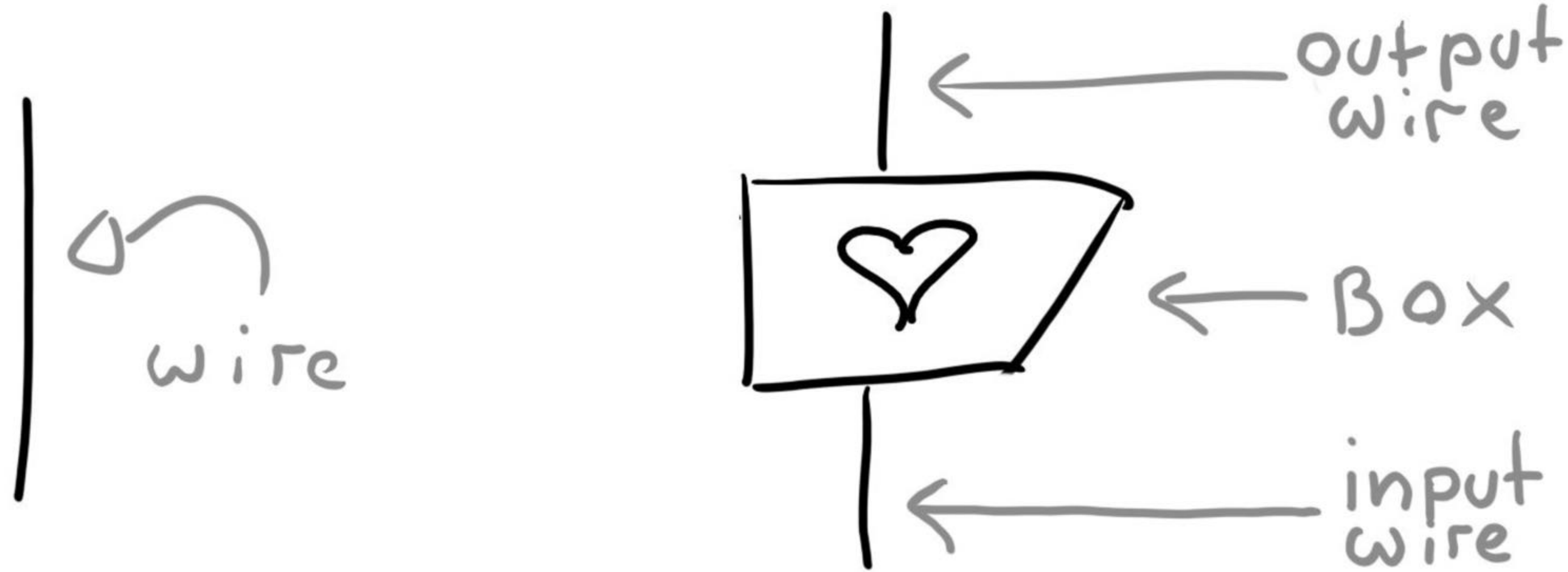
QUANTUM IN PICTURES

BOB COECKE & STEFANO GOGIOSO

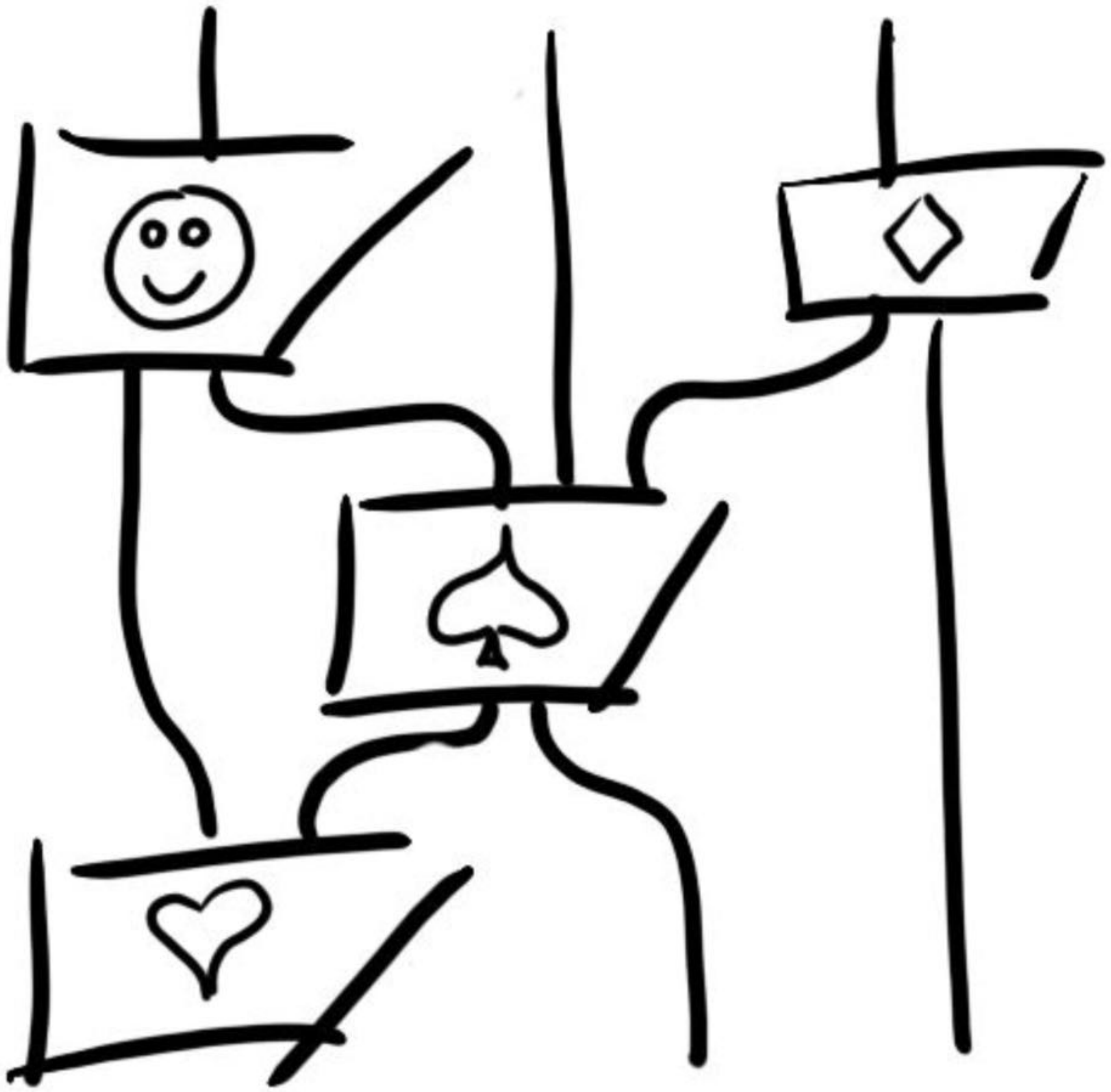

45°
270°
2 LEGS

Chapter 1: wires and boxes

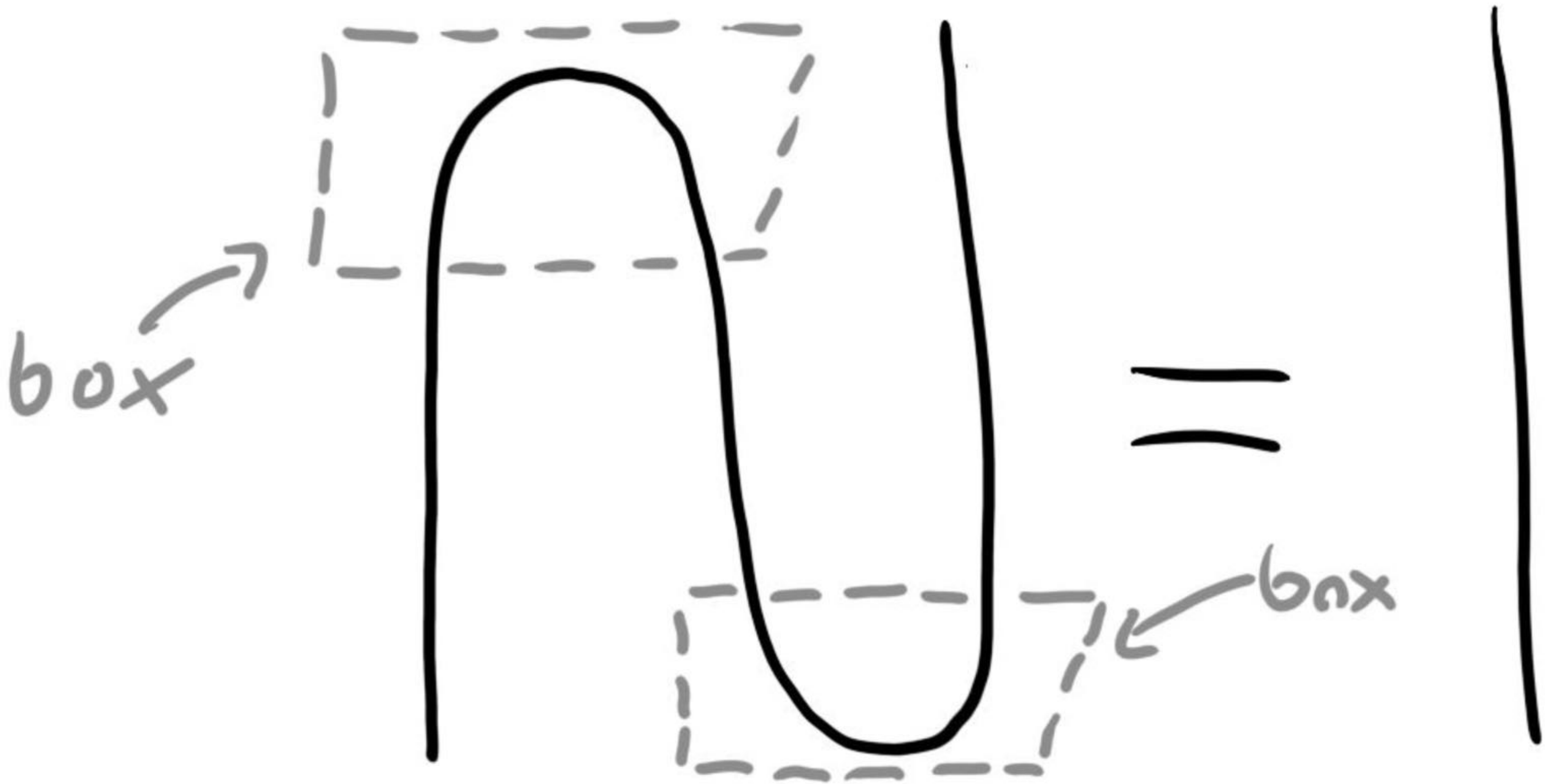
– *wires and boxes as mathematics* –



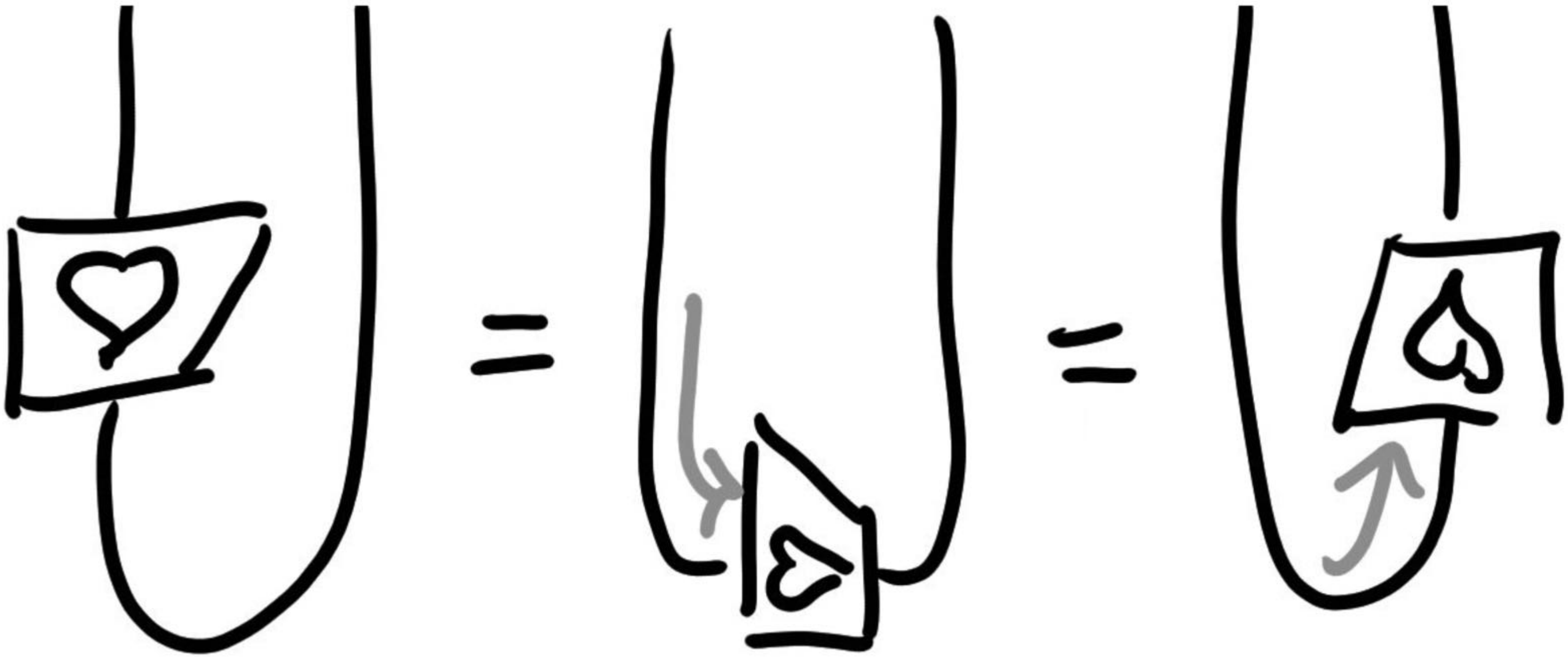
– wires and boxes as mathematics –



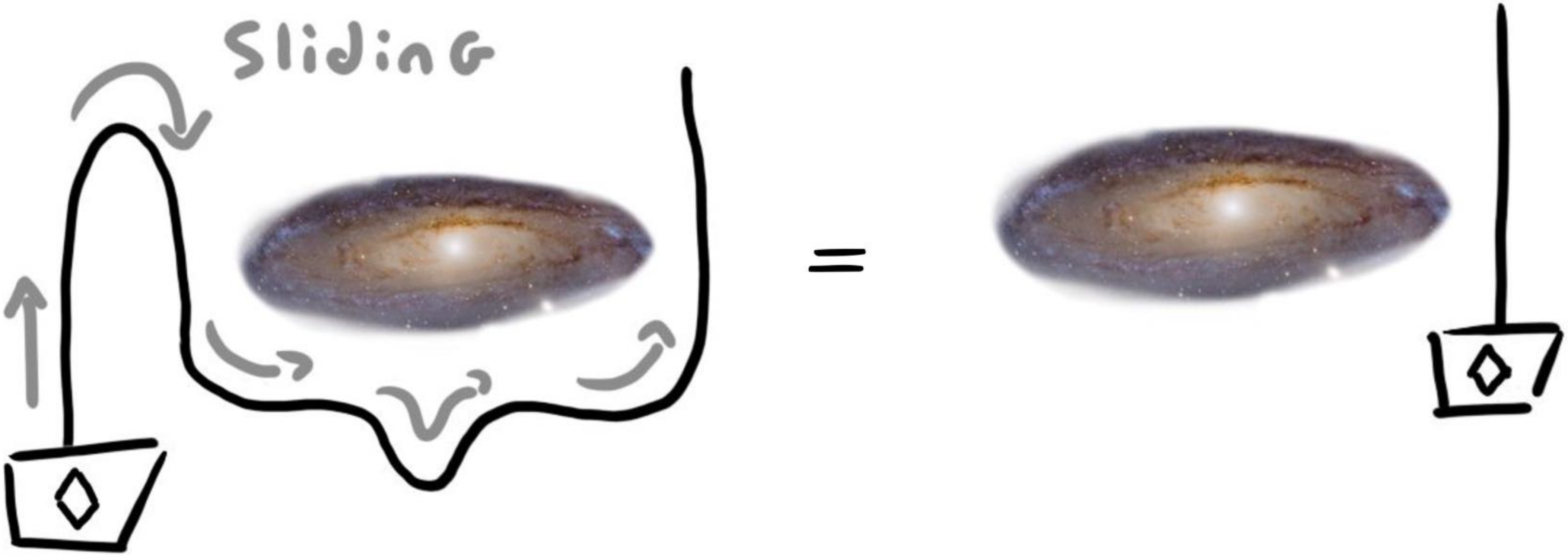
– cup and cap boxes –



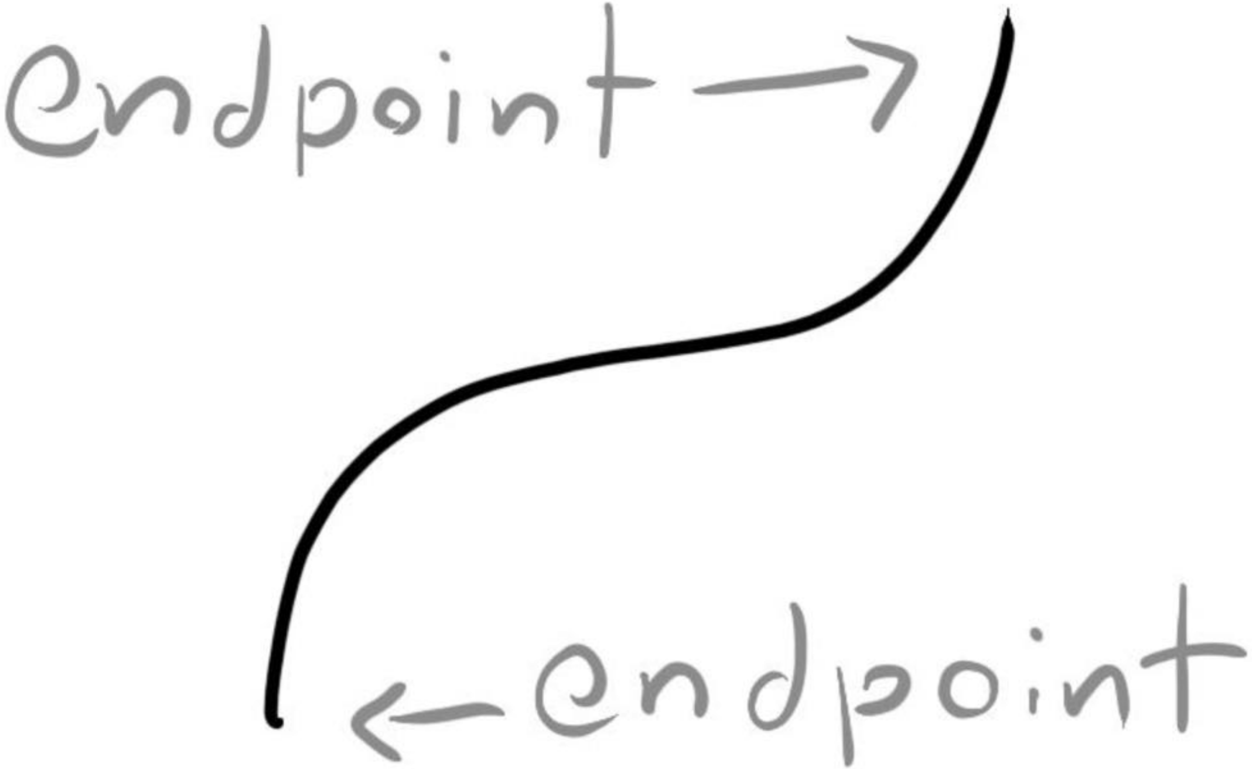
– *cup and cap boxes* –



– teleportation –



Chapter 2: spiders is all you need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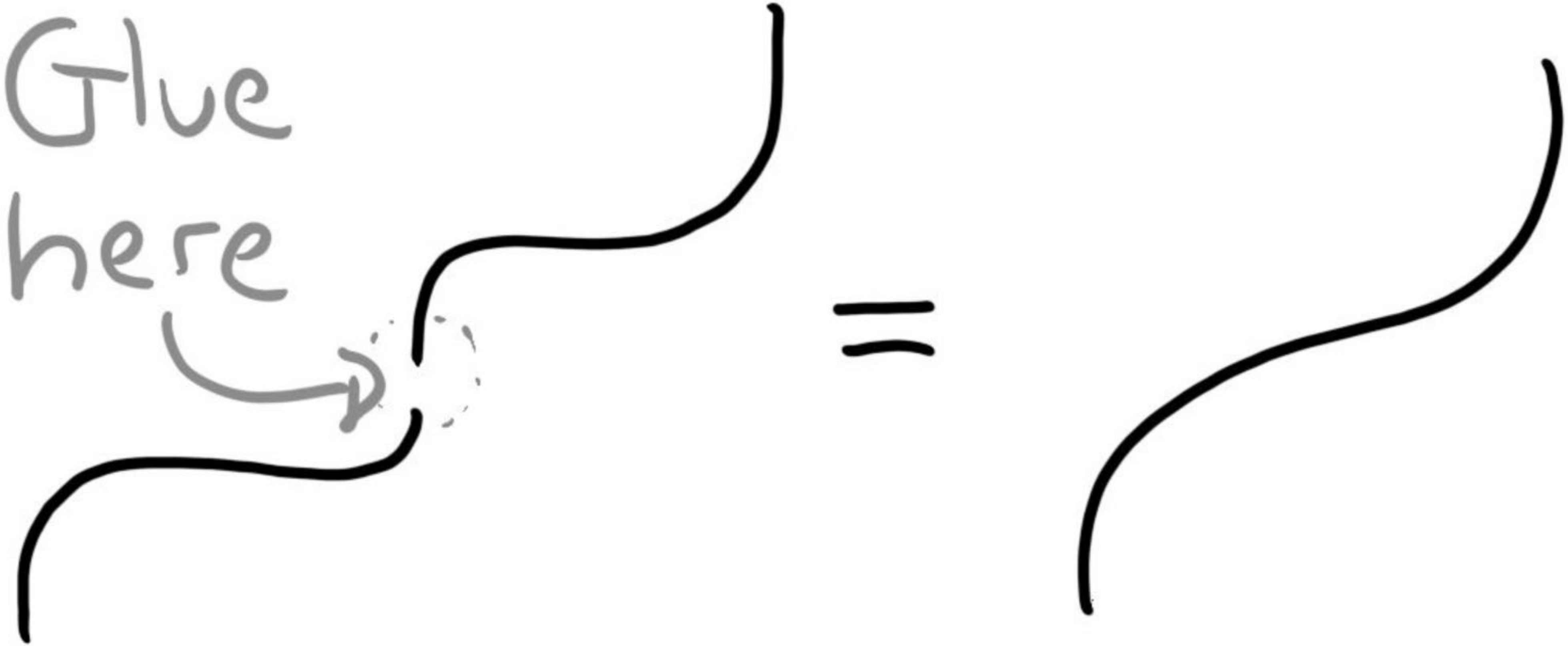
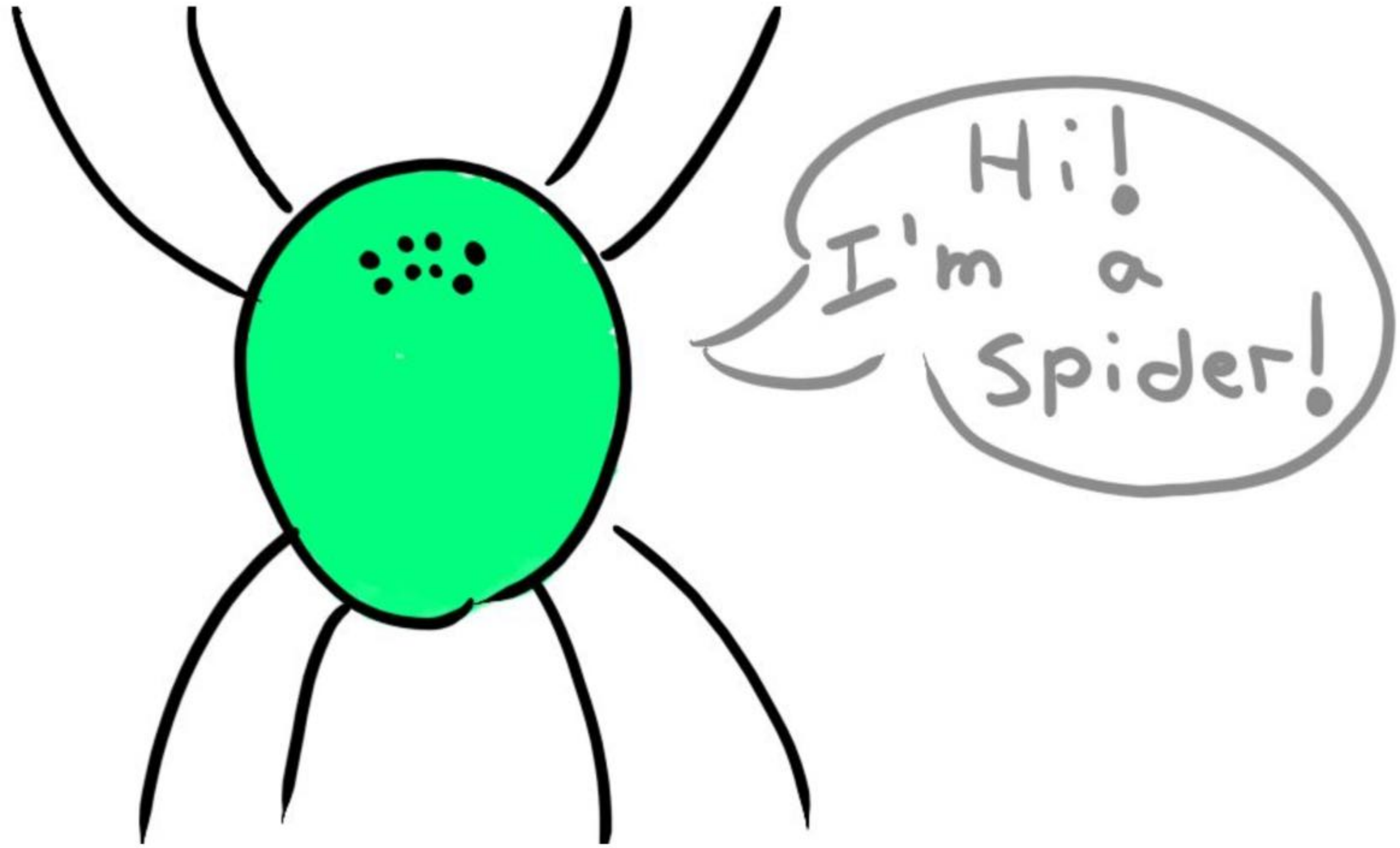
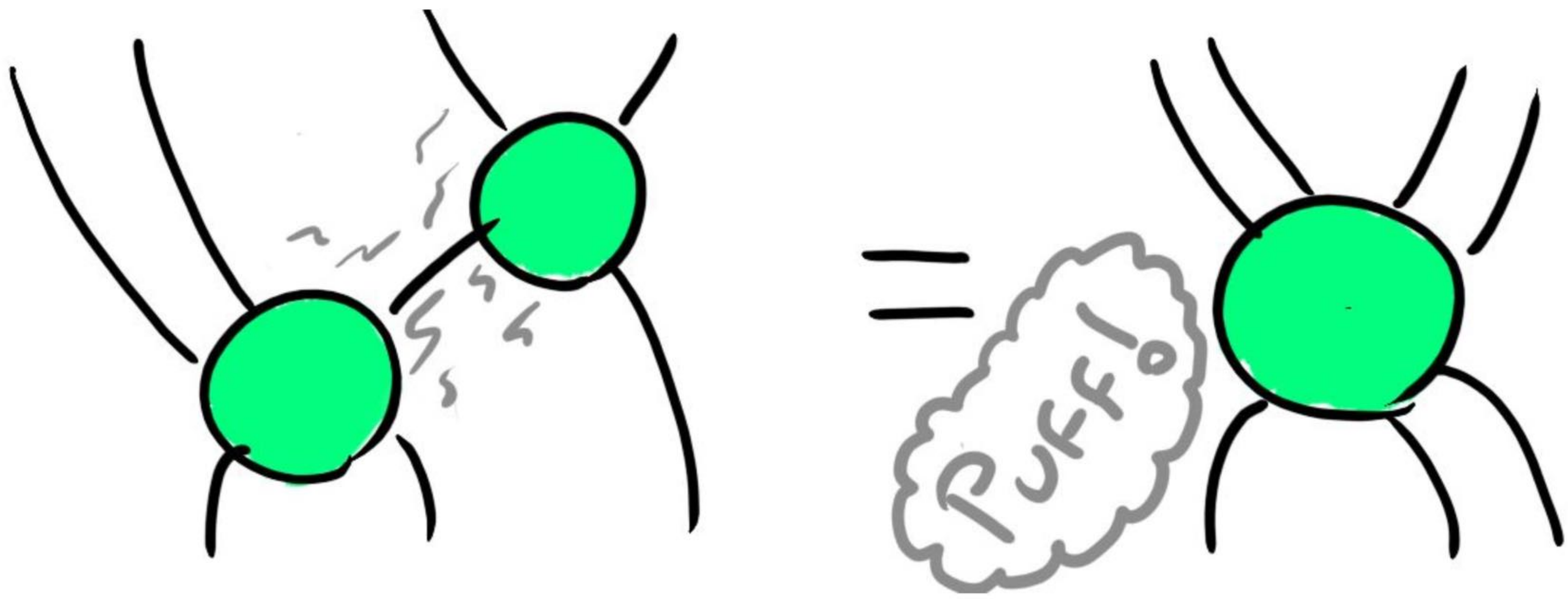

Glue here

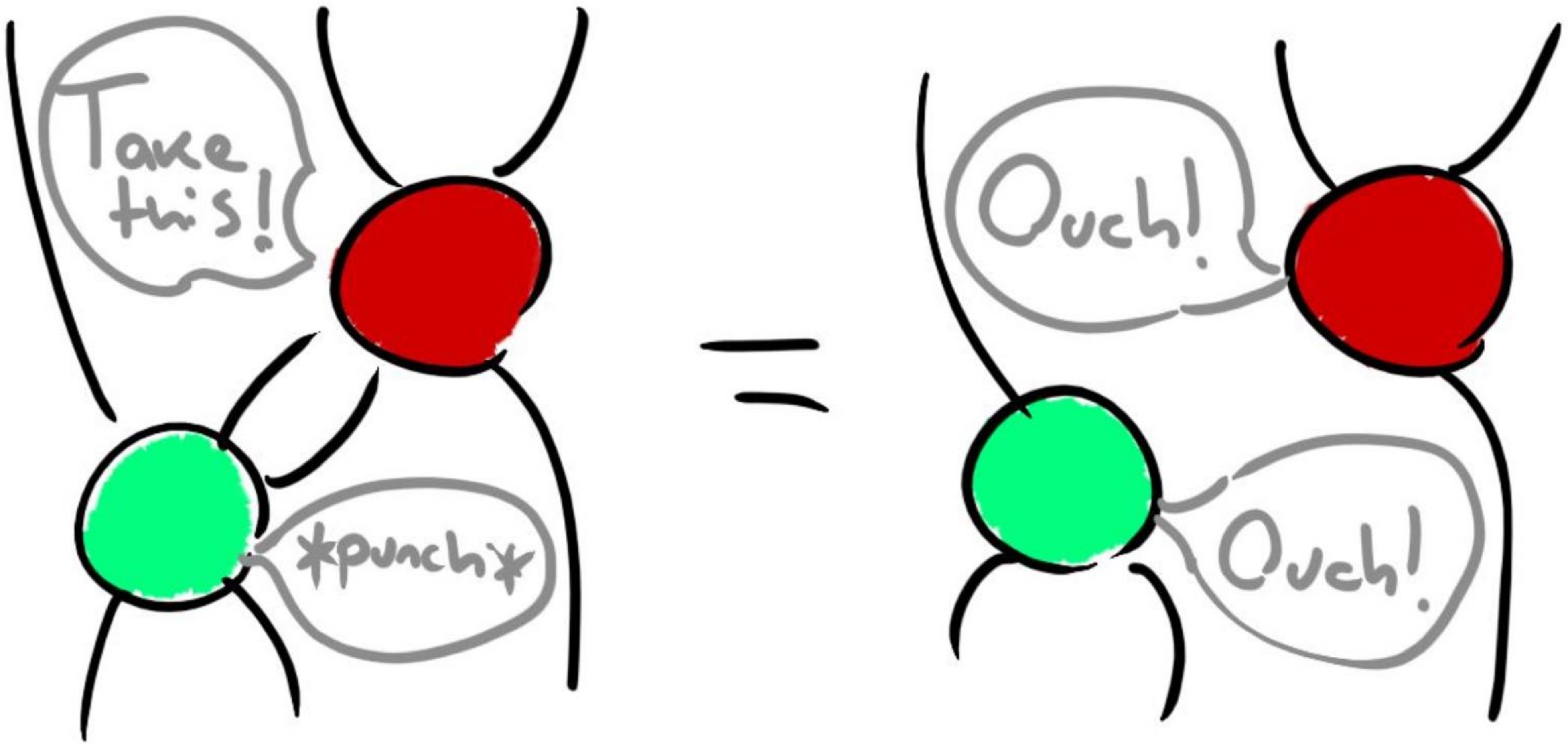
– from wires to spiders –



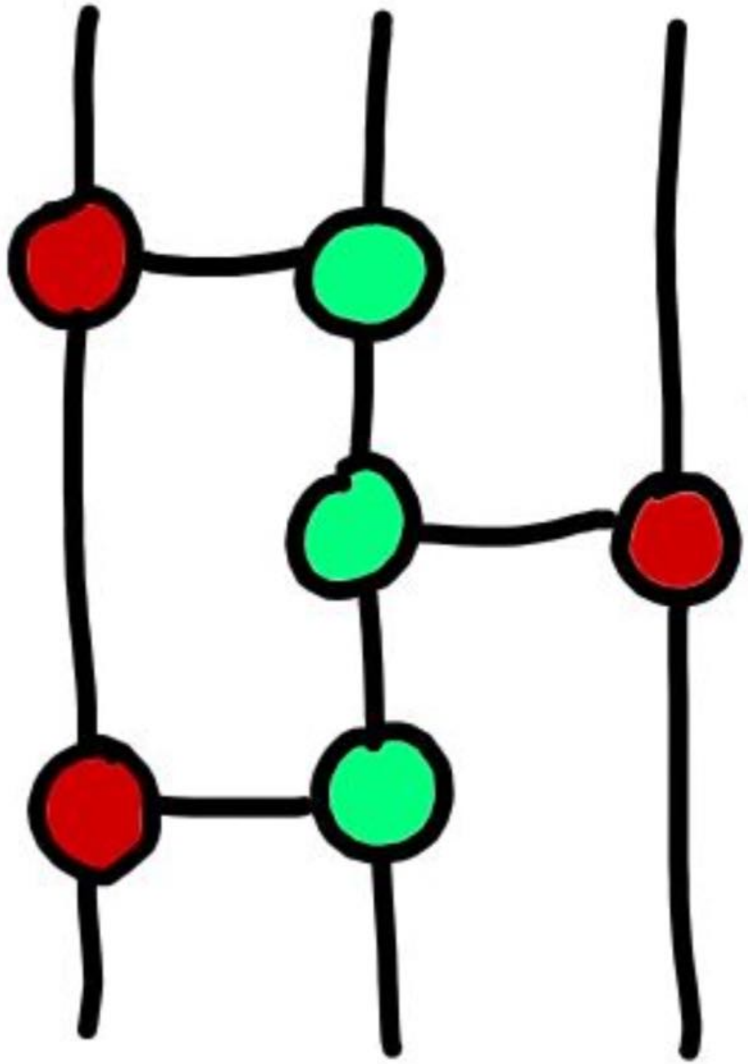
– from wires to spiders –



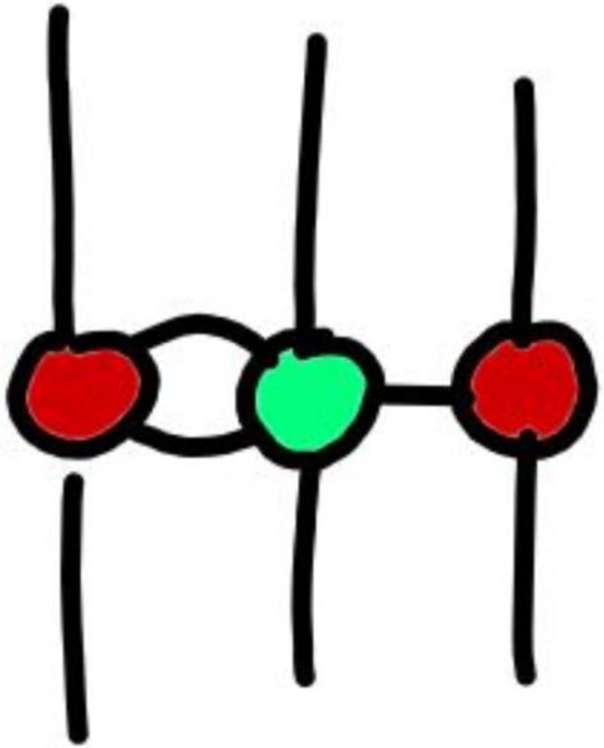
– coloured spiders –



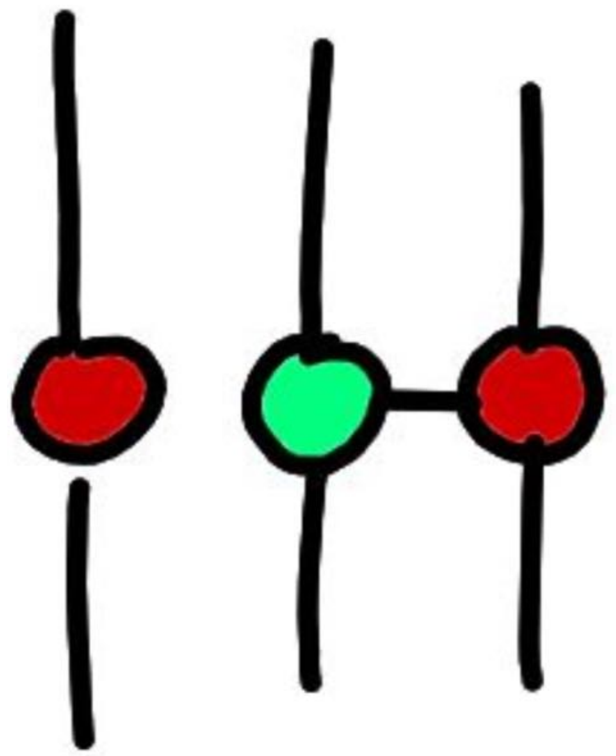
– quantum circuits –



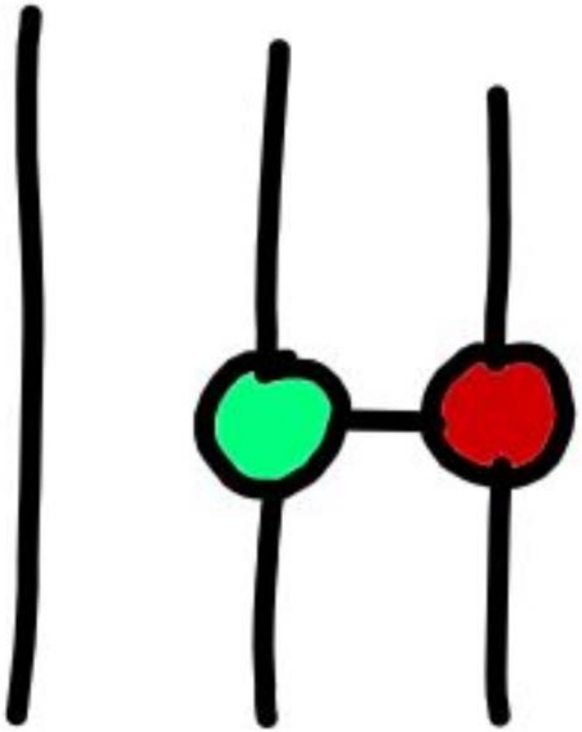
– quantum circuits –



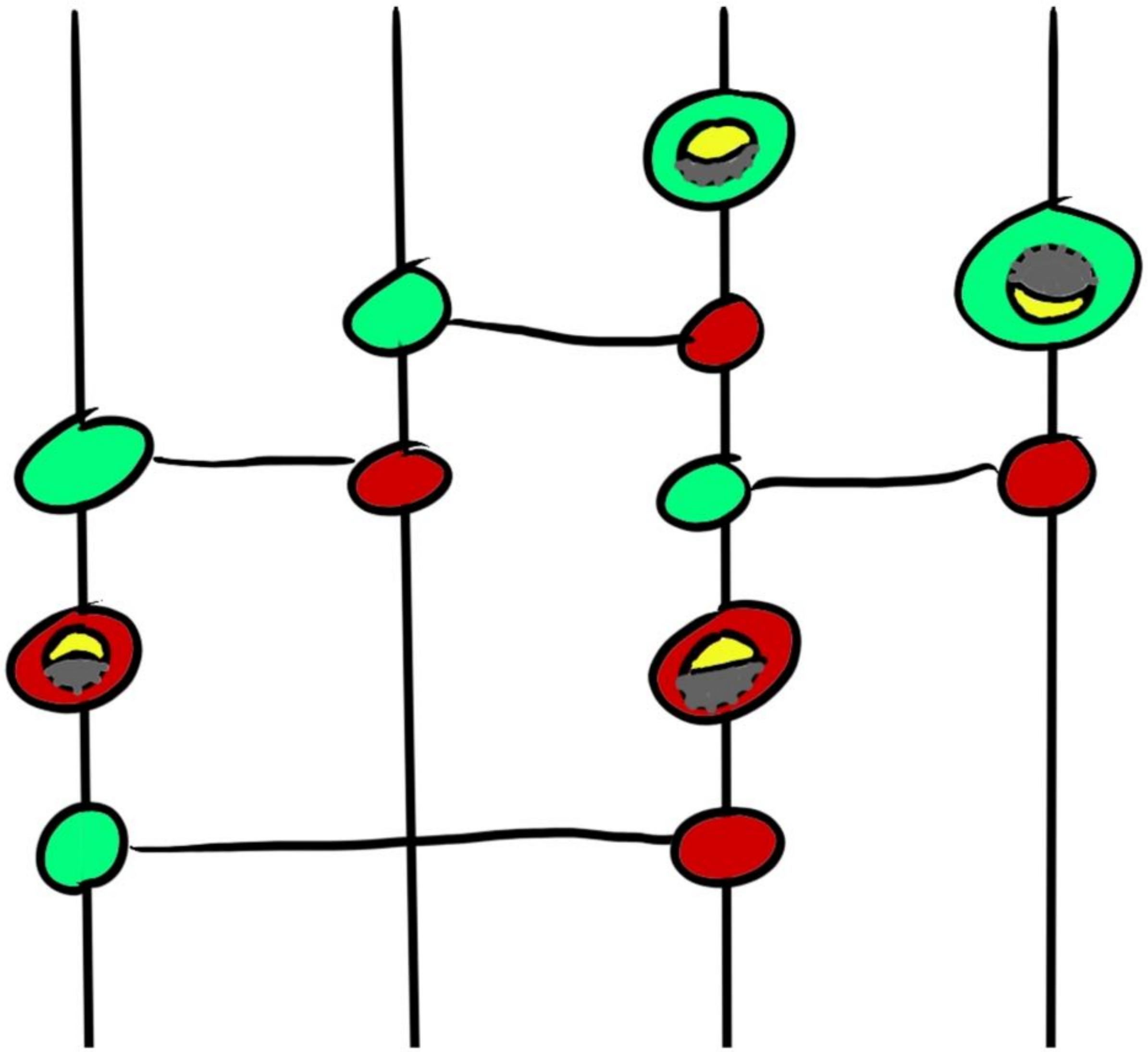
– quantum circuits –



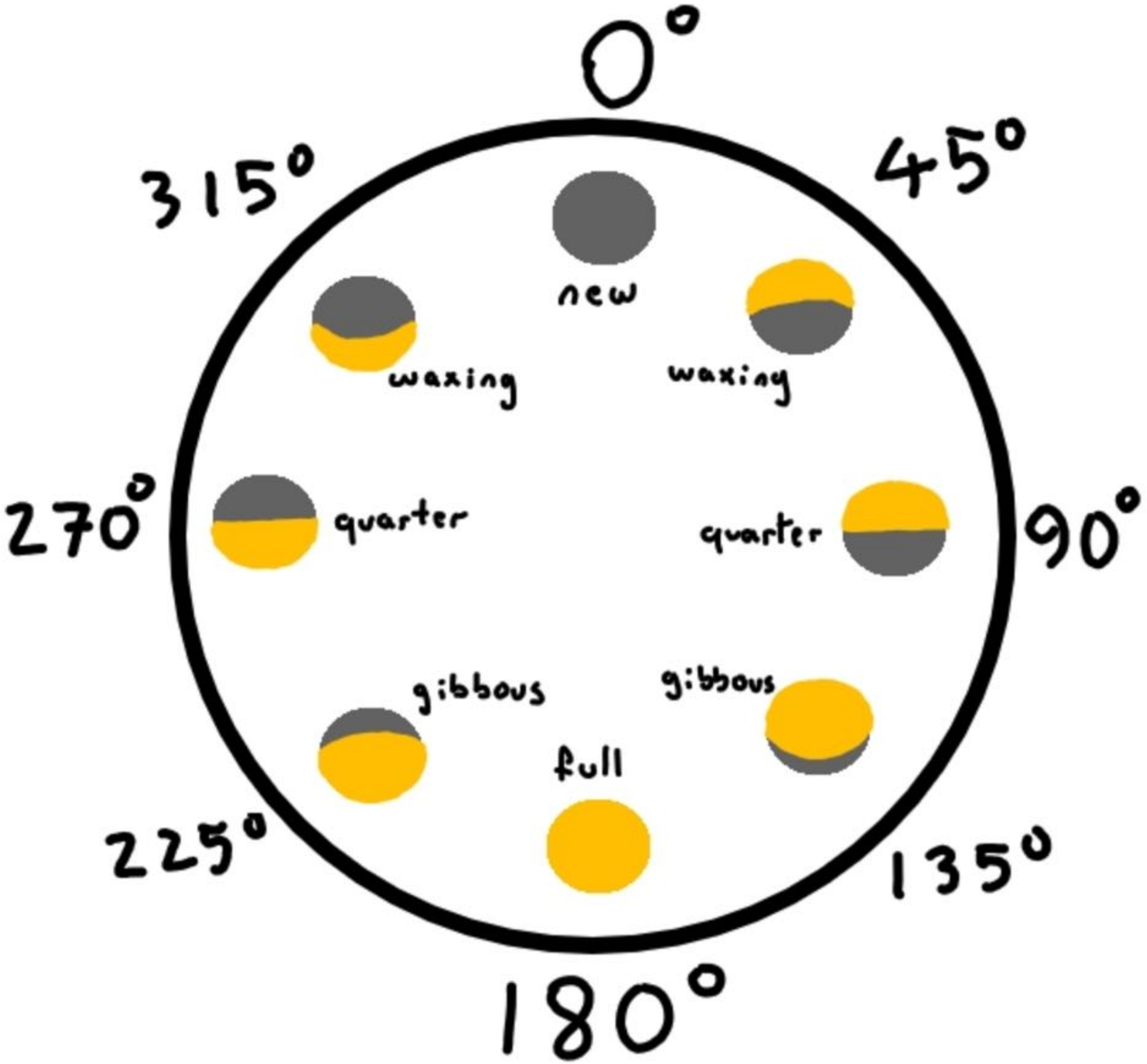
– *quantum circuits* –



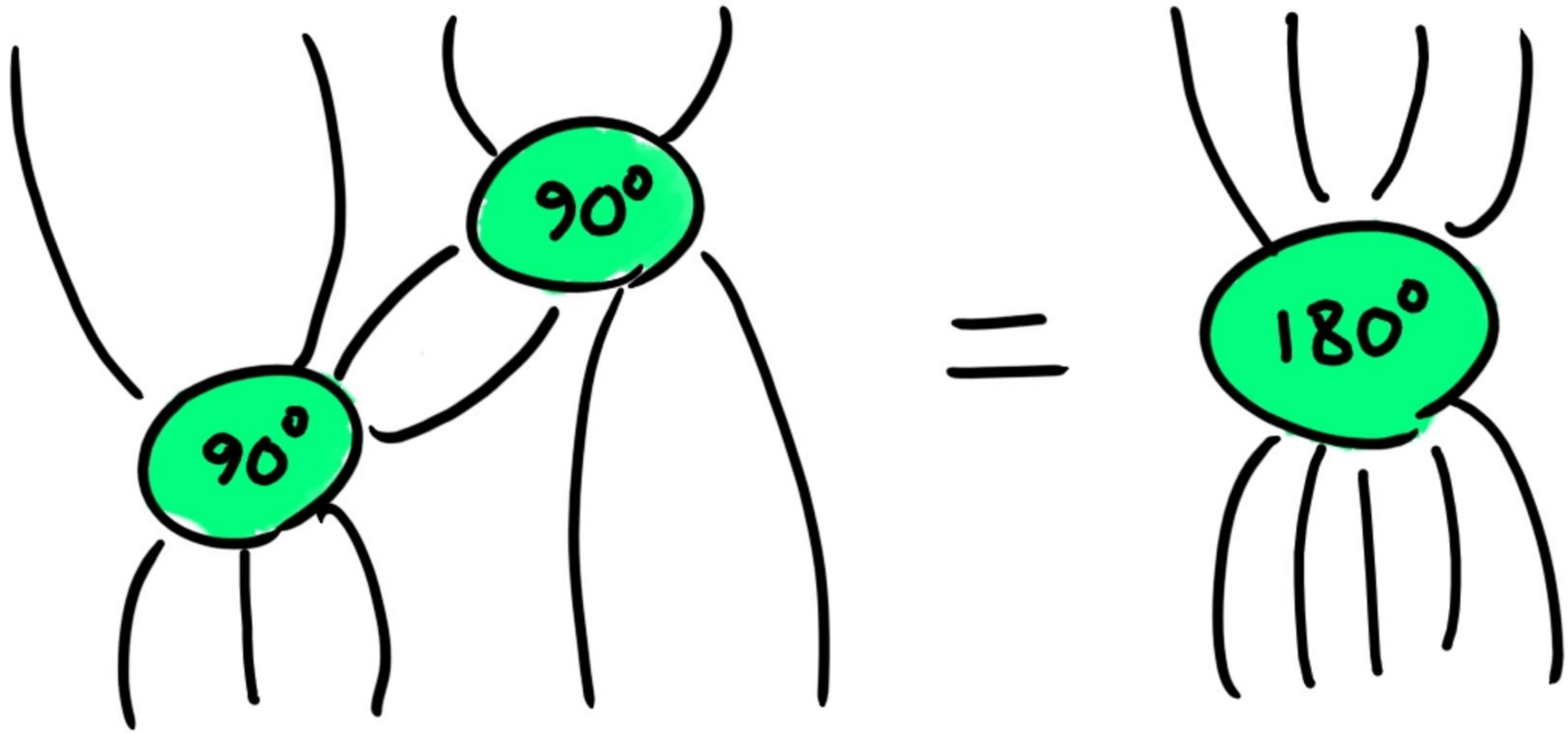
– spiders with phases –



– spiders with phases –

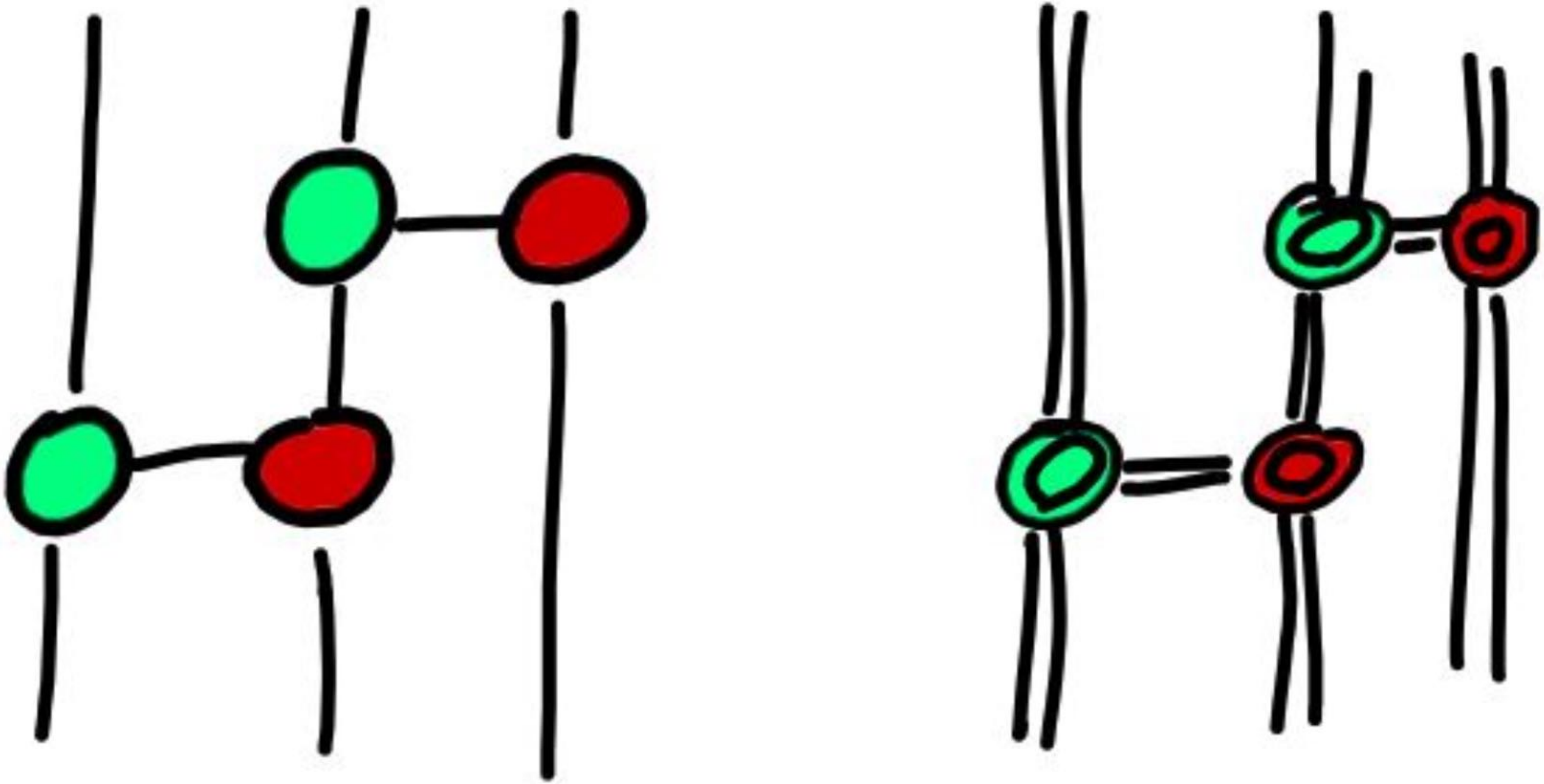


– spiders with phases –

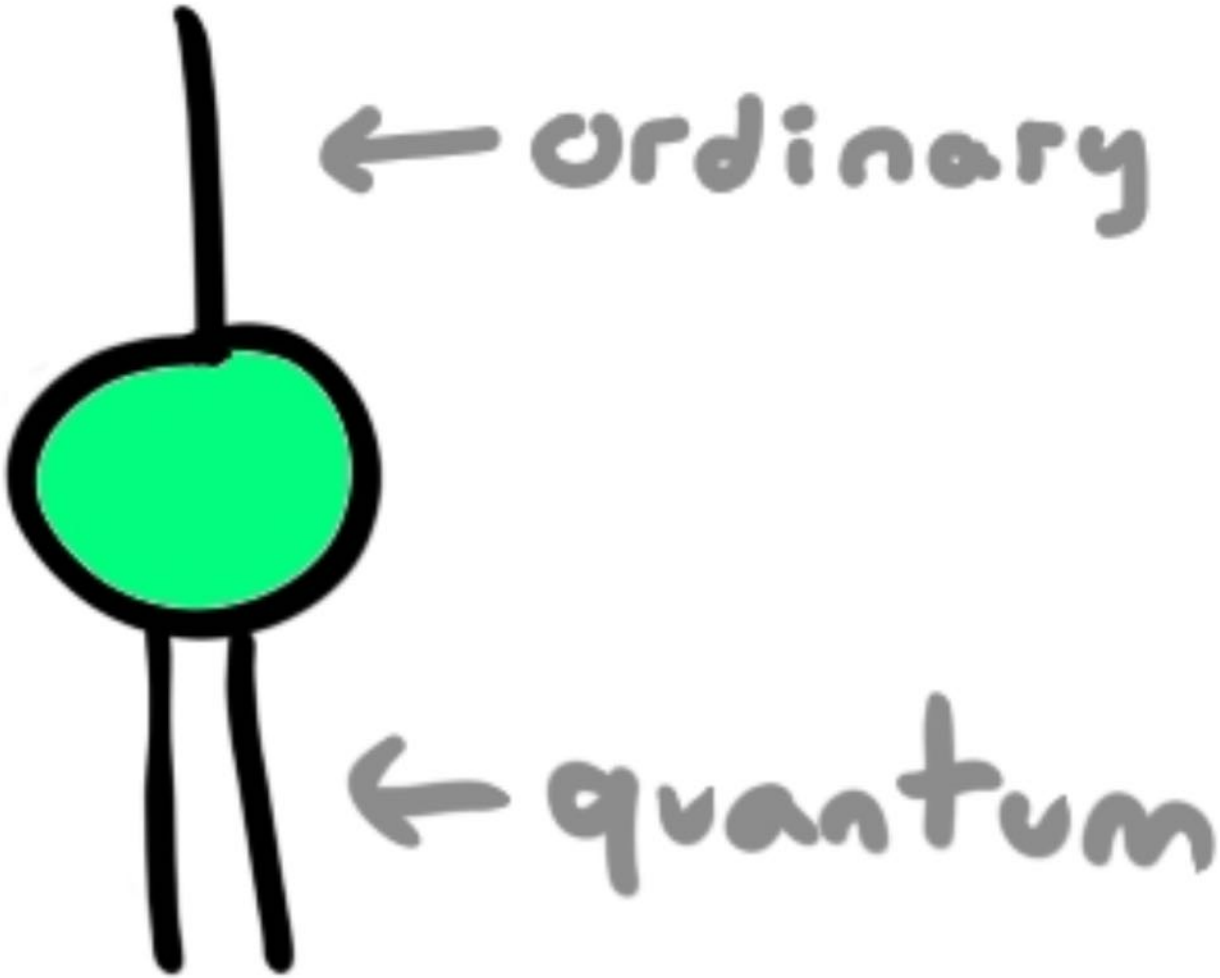


Chapter 4: classical vs. quantum wires

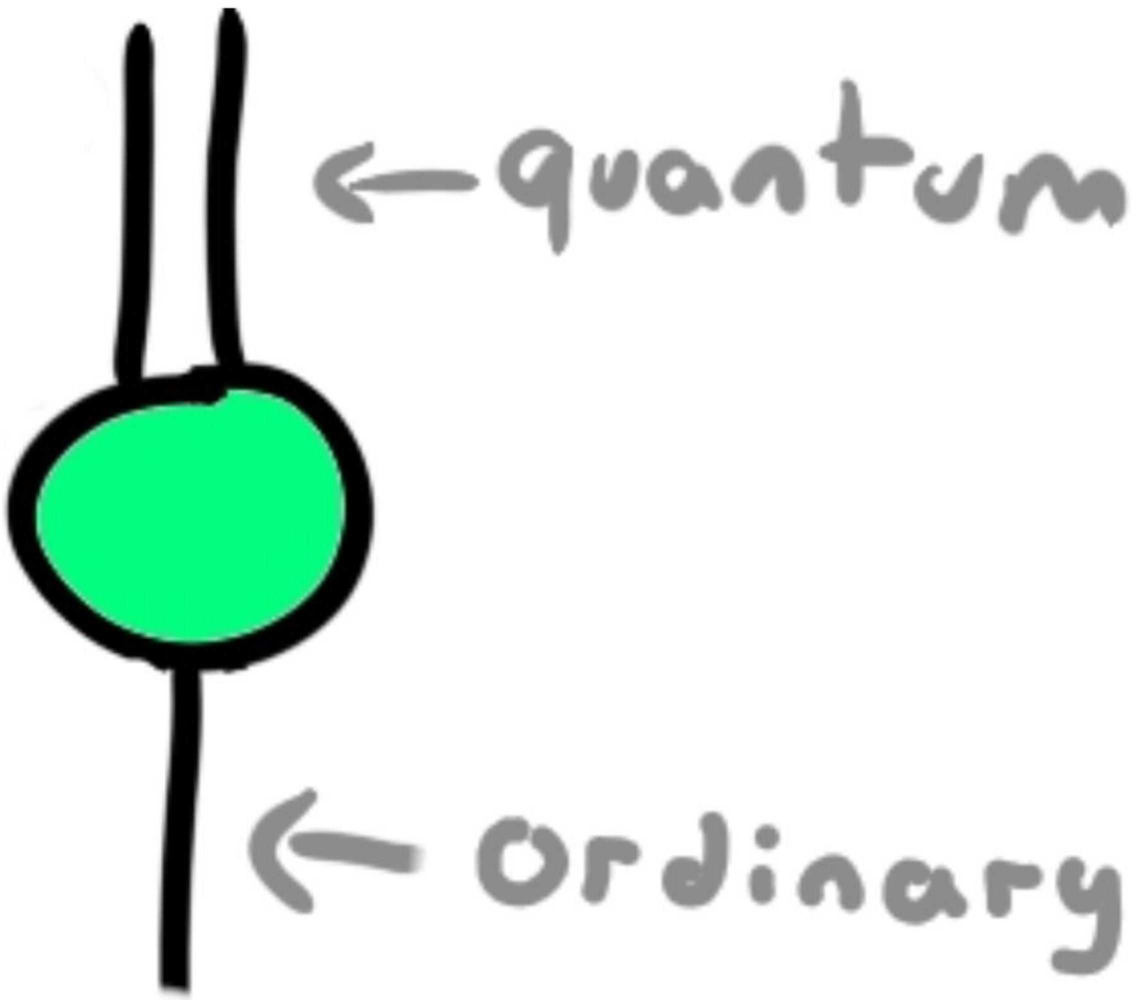
– quantum vs. ordinary wires –



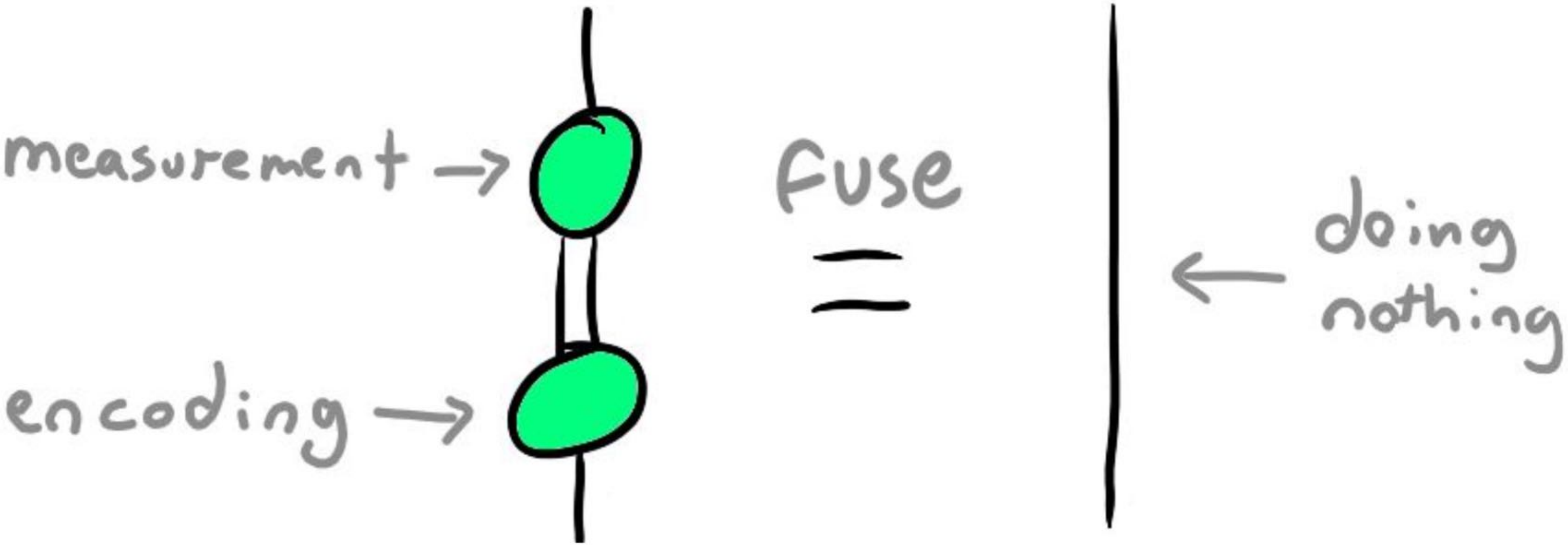
– *measurement* –



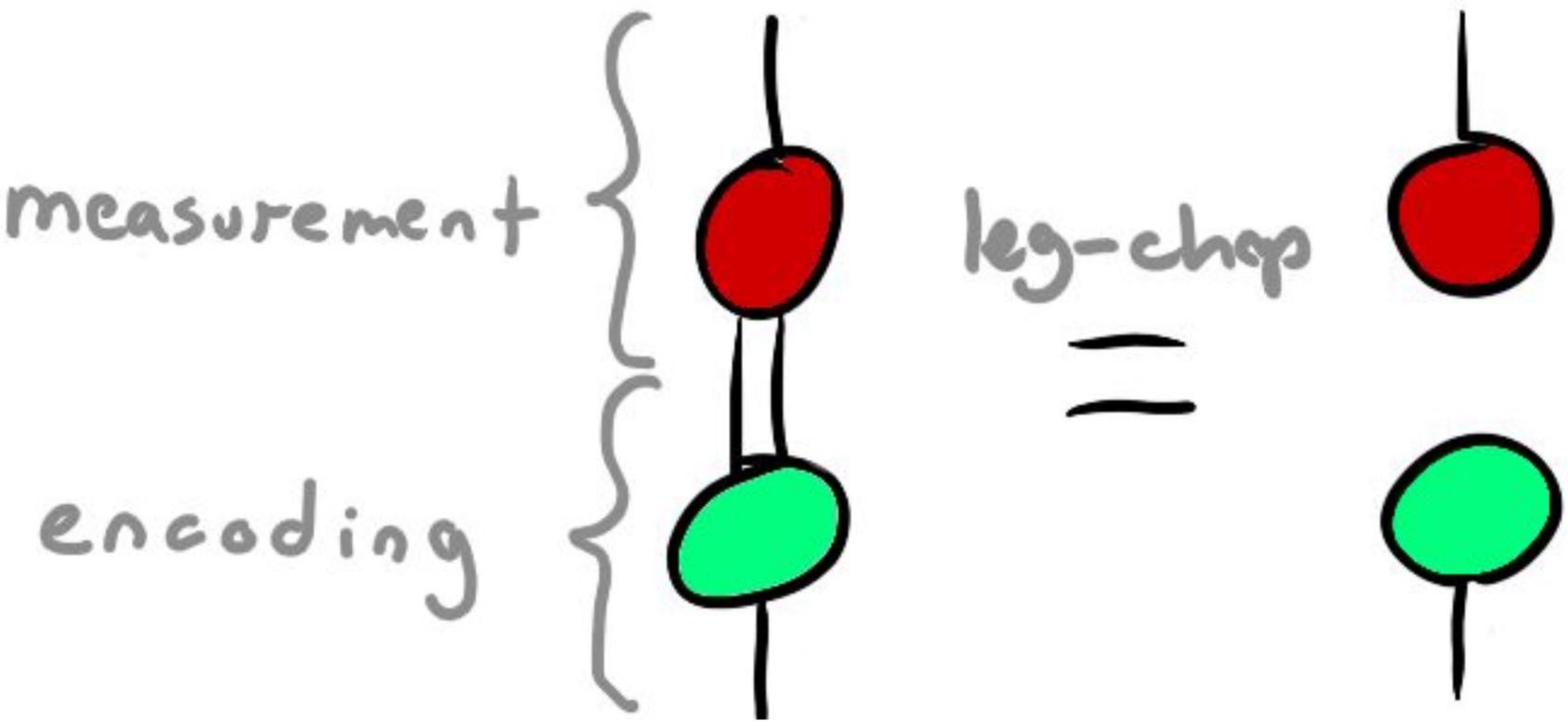
– *encoding* –



– measurement after encoding –

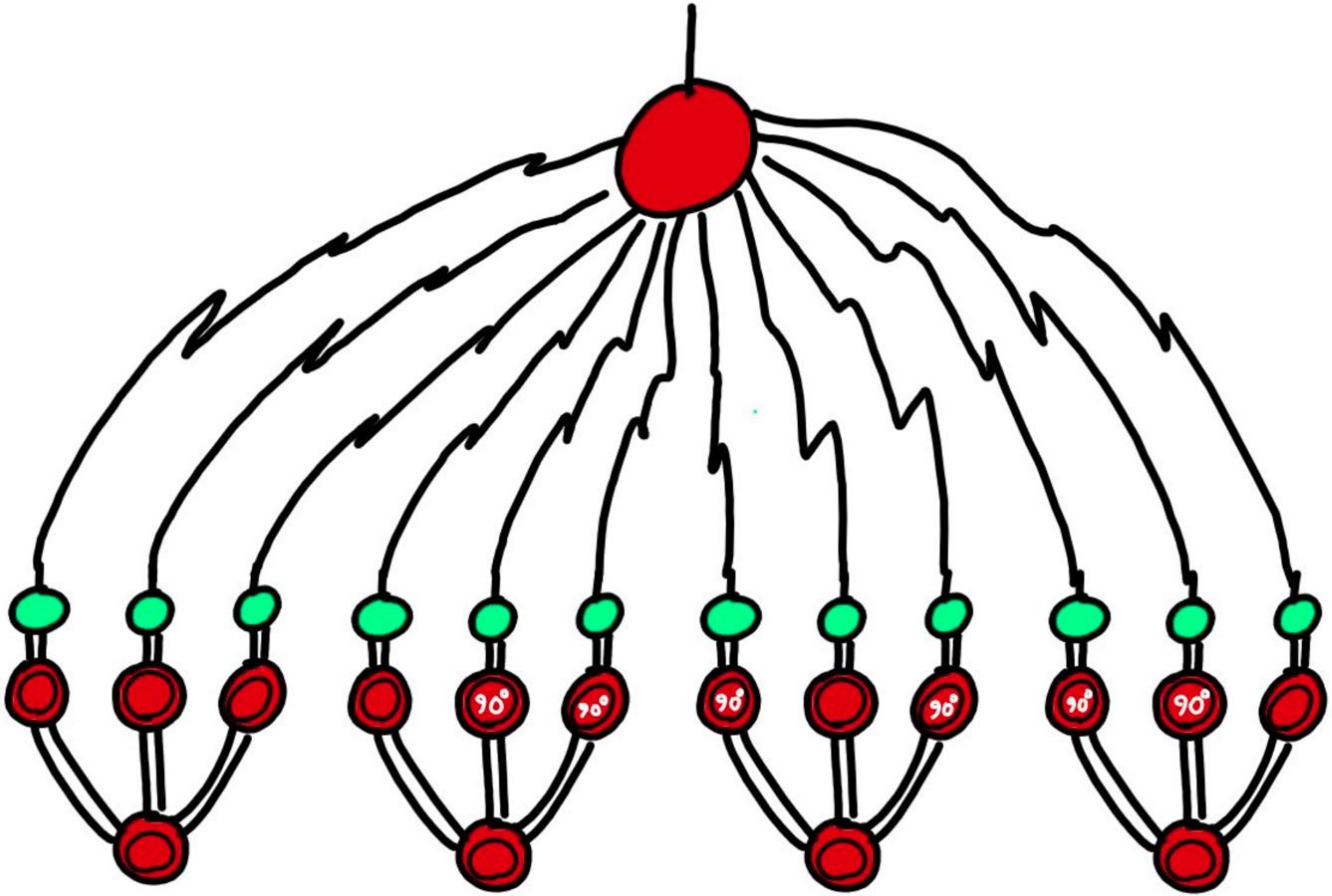


– measurement after encoding –

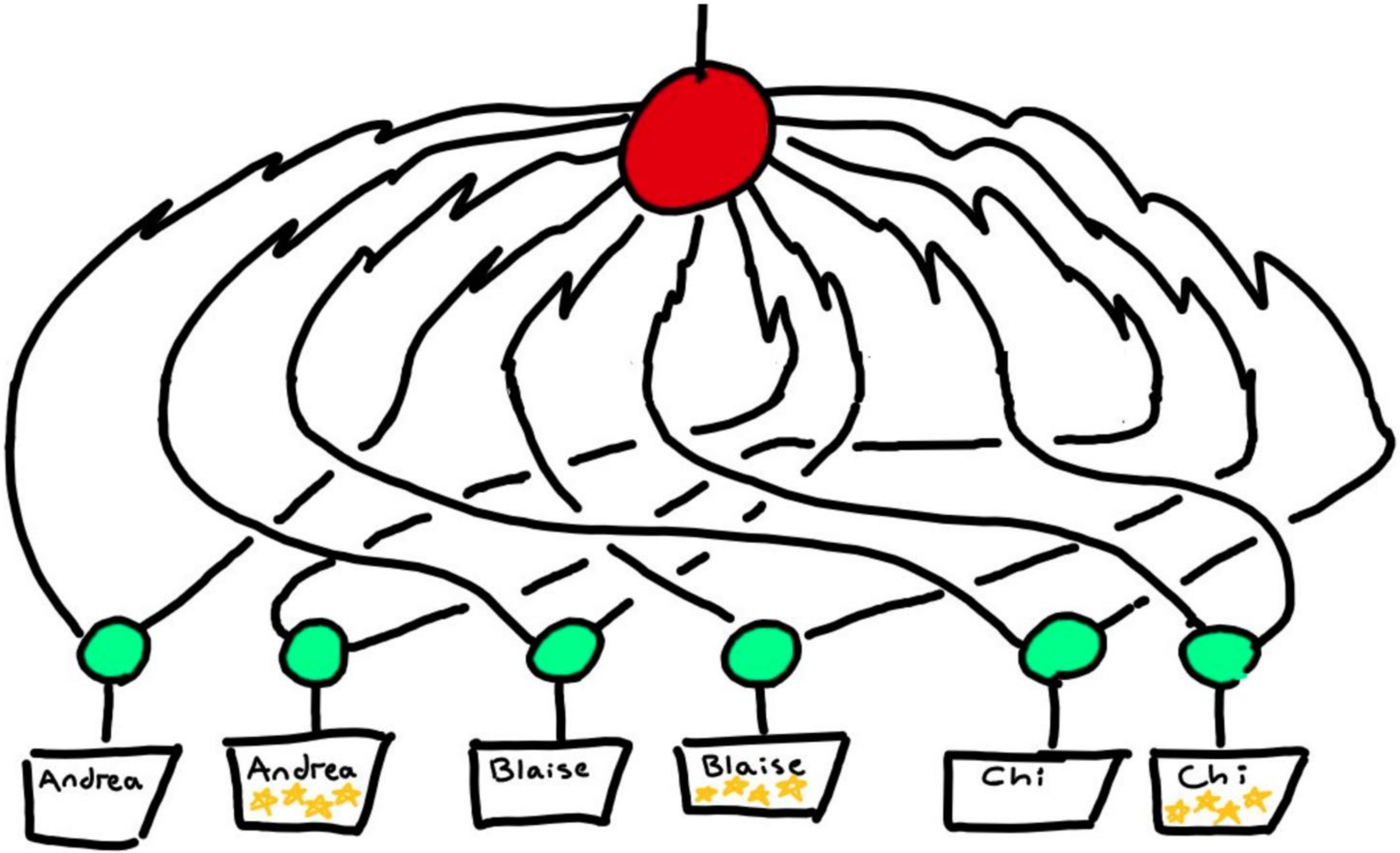


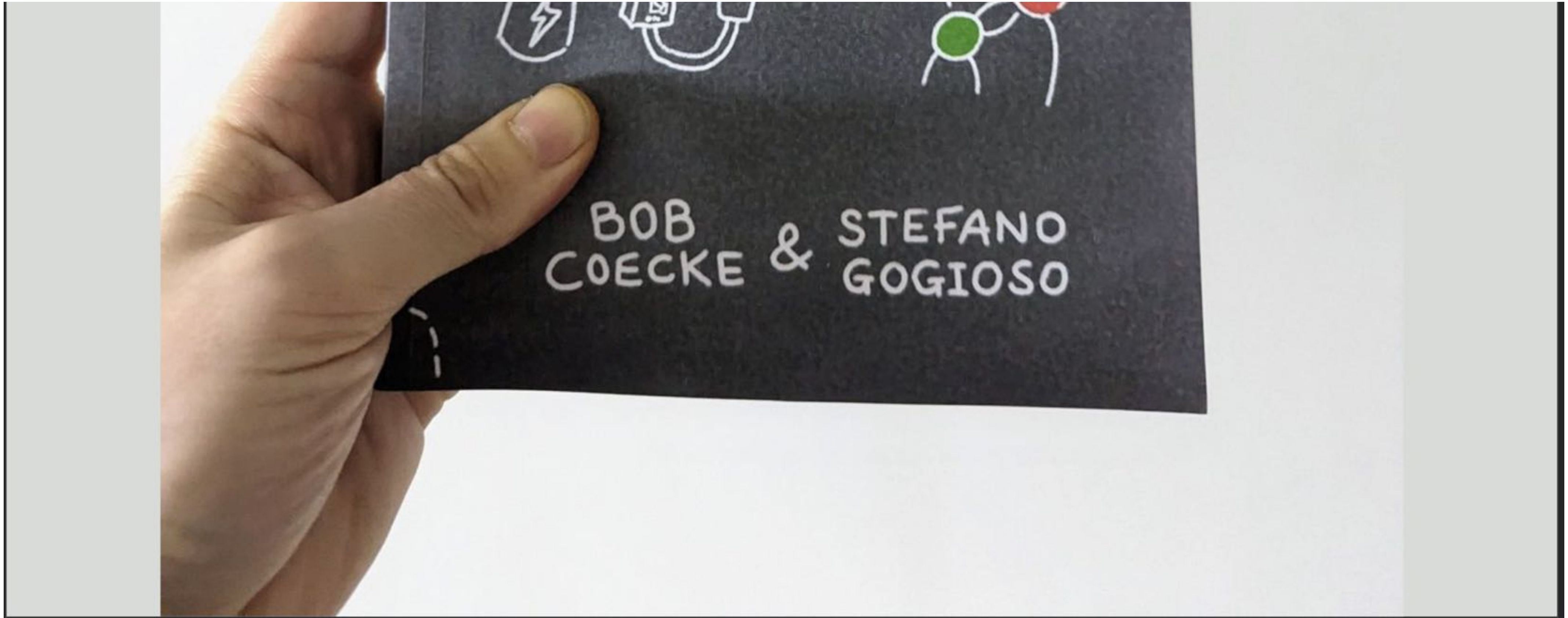
Chapter 6: 2022 Nobel Prize

– 2022 Nobel Prize –



– 2022 Nobel Prize –

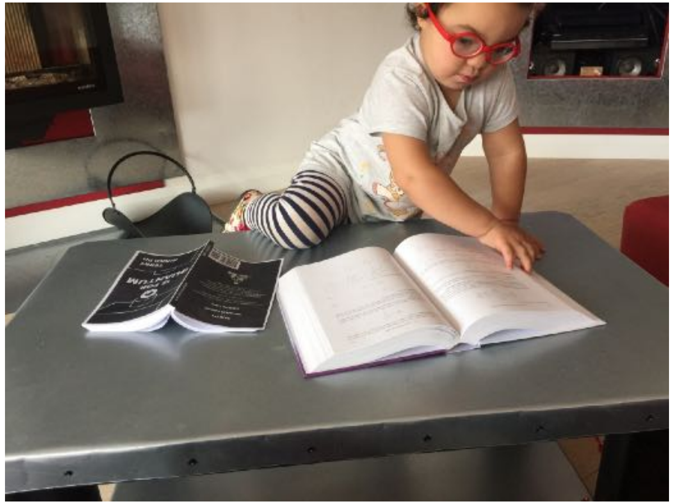




Dan Razvan Ghica

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!!!

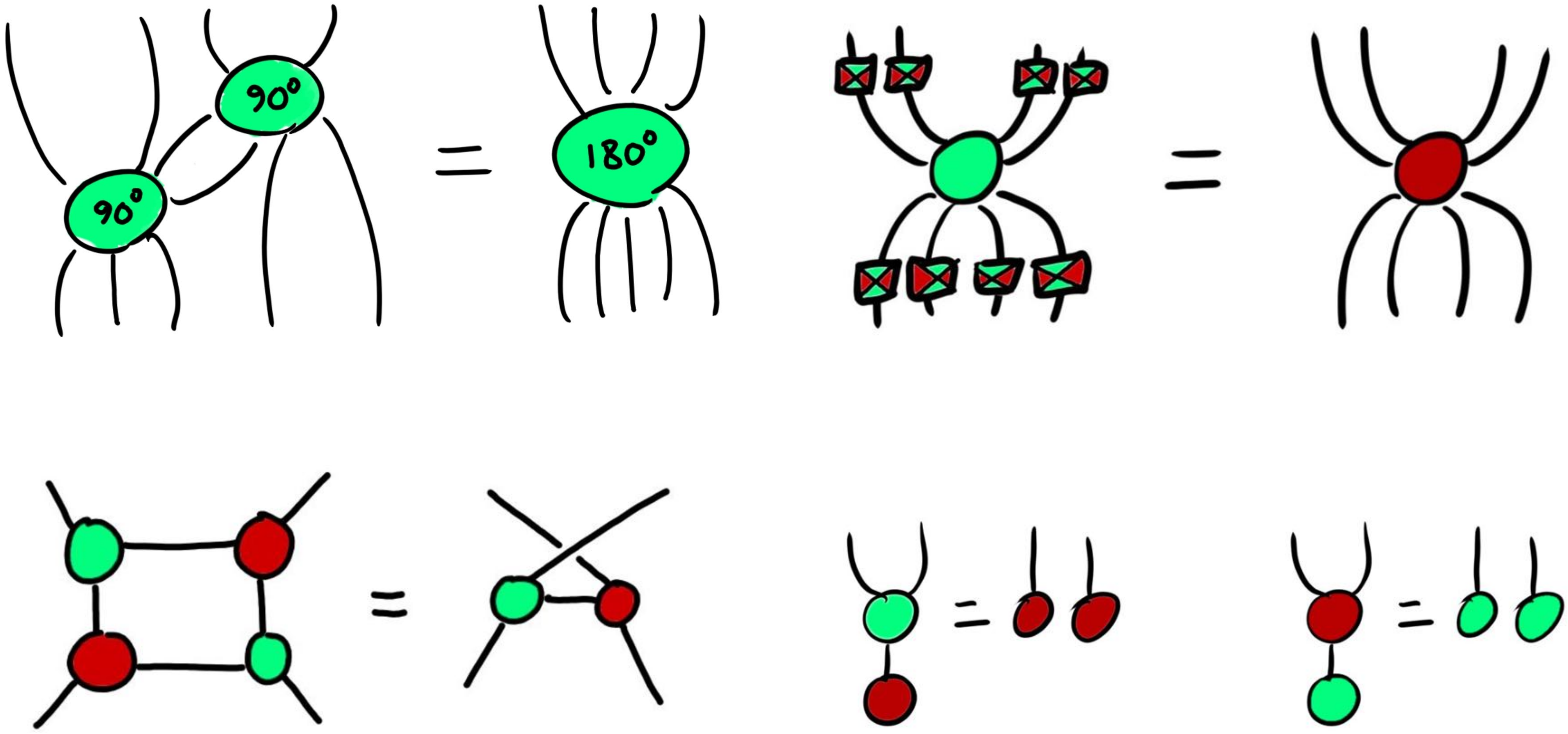
ZX-calculus (2007) - first paper

A graphical calculus for quantum observables

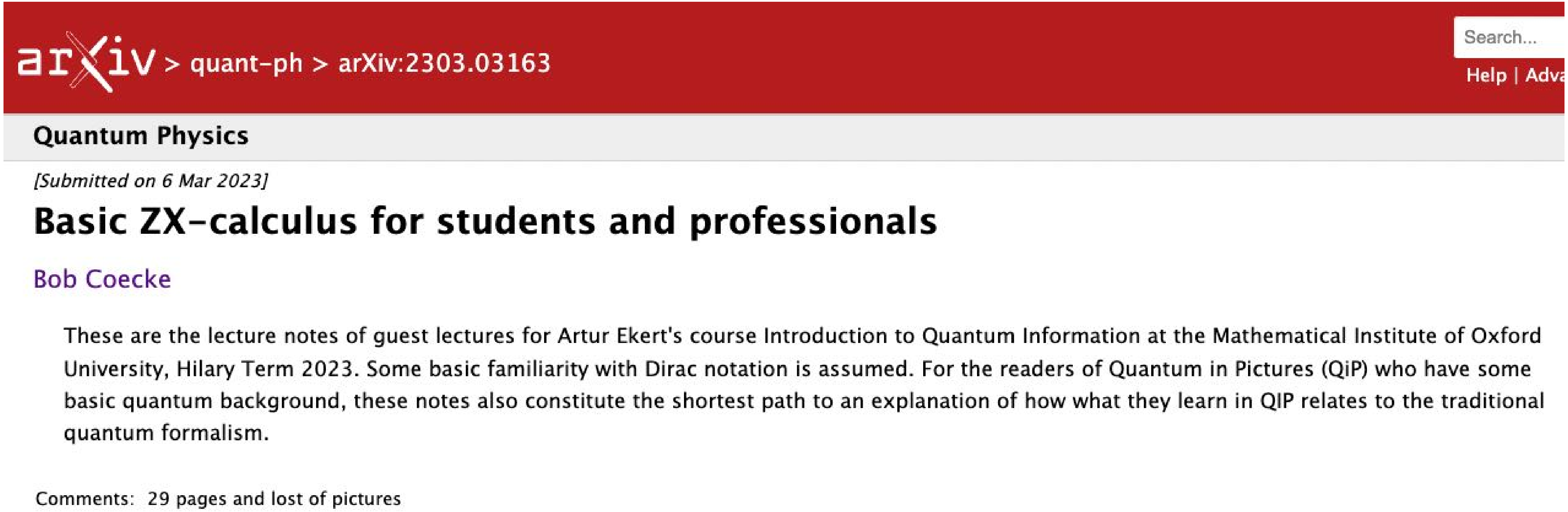
Bob Coecke and Ross Duncan
Oxford University Computing Laboratory

We present novel laws describing the interaction of a pair of mutually unbiased observables. These laws yield a diagrammatic calculus which enables matrix-free reasoning about quantum systems. To illustrate the elegance of this approach we establish some properties of standard quantum logic gates, compute the quantum Fourier transform and demonstrate equivalence between certain cluster state and quantum circuit computations.

– ”ZX-calculus” –

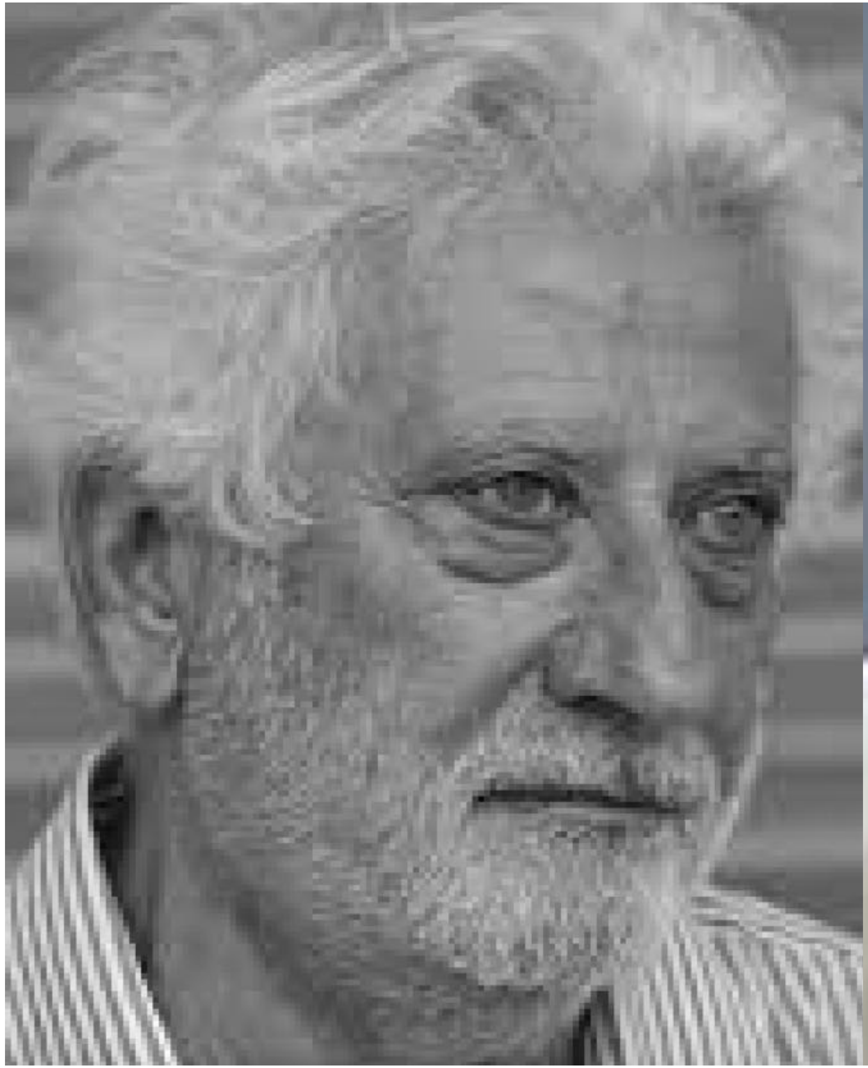


ZX-calculus (2023) - in a few toilet sittings



Aurelio Carboni, Bob Walters & Steve Lack

Aurelio Carboni, Bob Walters & Steve Lack (& doubly-interacting & phases)



circuit optim

optical MBQC

error-corr/surg

q-crypto

other

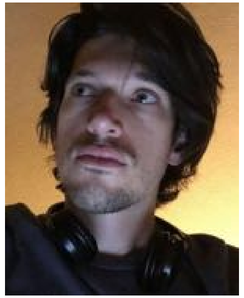
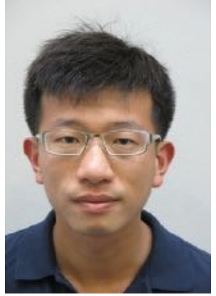
pro education

mass education

quantum AI

chem/bio

Completeness!

Two complete axiomatisations of pure-state qubit quantum computing

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

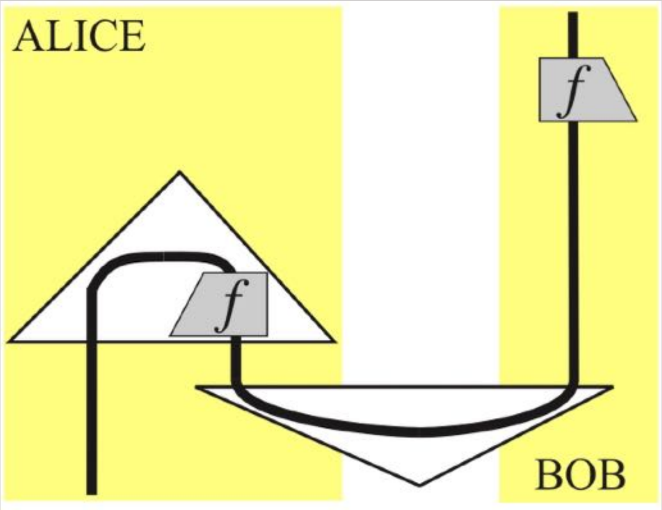
LICS '18: Proceedings of the 33rd Annual ACM/IEEE Symposium on Logic in Computer Science • July 2018 • Pages 502–511 • https://doi.org/10.1145/3209108.3209128

Online: 09 July 2018 Publication History

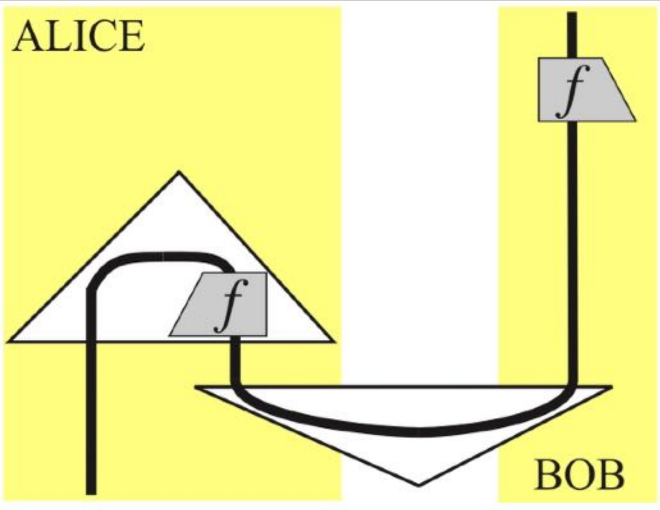
Jim Lambek

... back to 2005, Montreal ...

Hello, I present to you quantum teleportation:



Hello, I present to you quantum teleportation:



Bob!

This is grammar!

... 3 years later ...

Colleagues @ Oxford University

Colleagues @ Oxford University

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

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

grammar algebra

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

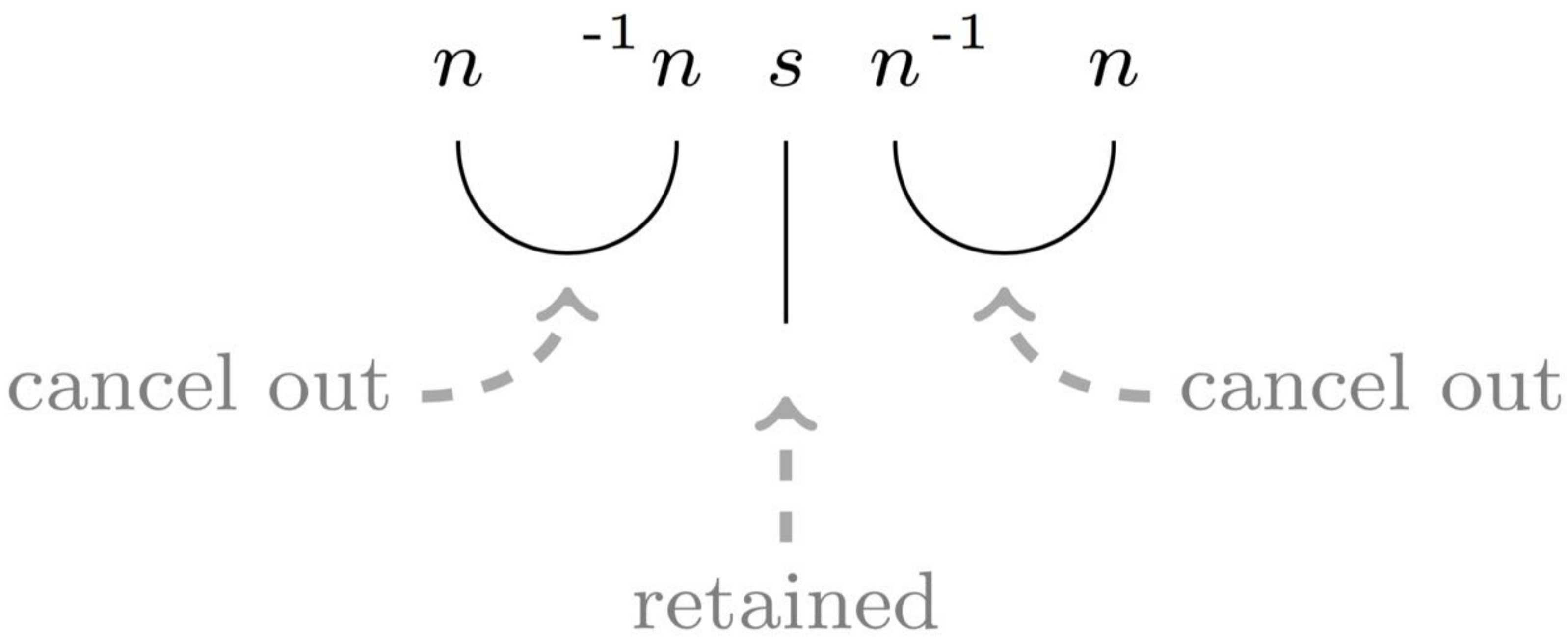
$$n \cdot {}^{-1}n \cdot s \cdot n^{-1} \cdot n \leq s$$

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:

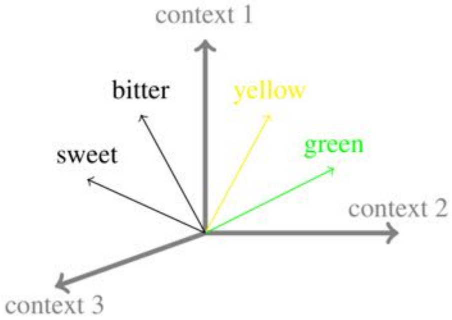


Colleagues @ Oxford University

- ...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**:

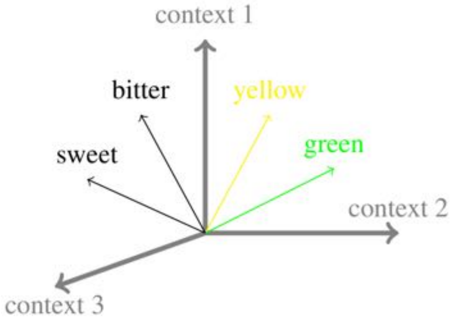


Colleagues @ Oxford University

- ...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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Help | Advance

Computer Science > Computation and Language

[Submitted on 23 Mar 2010]

Mathematical Foundations for a Compositional Distributional Model of Meaning

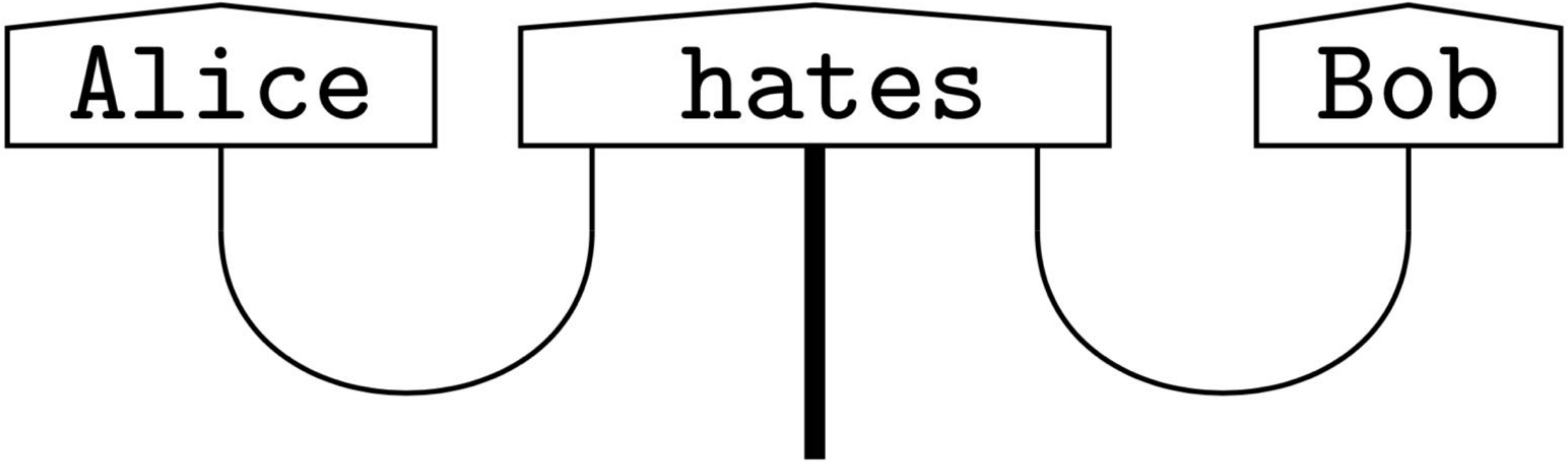
Bob Coecke, Mehrnoosh Sadrzadeh, Stephen Clark

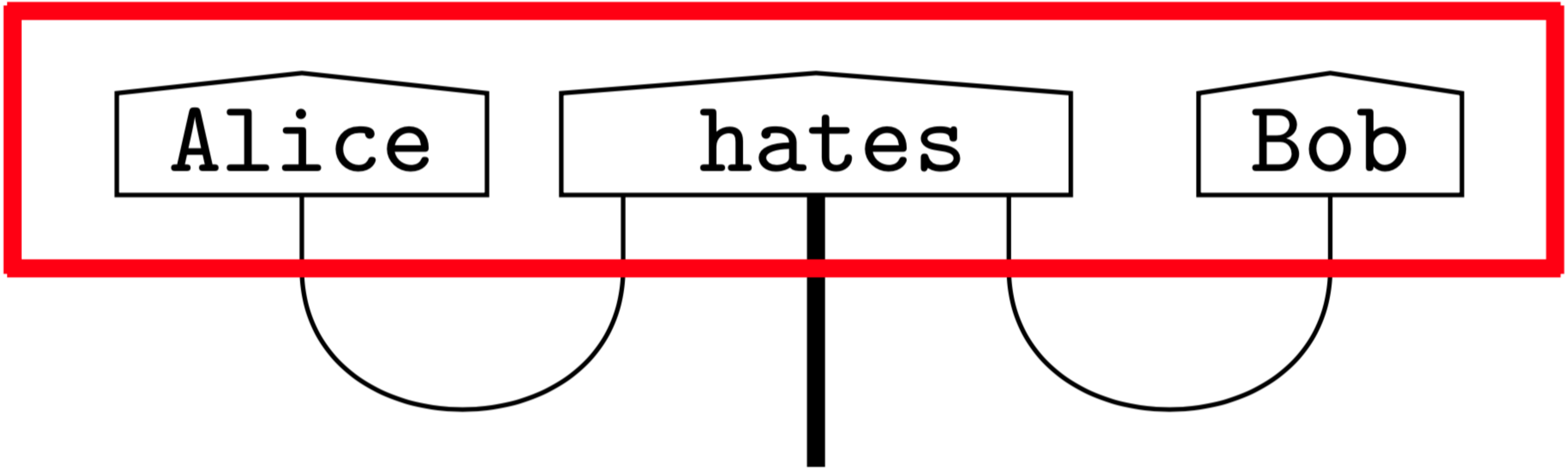
We propose a mathematical framework for a unification of the distributional theory of meaning in terms of vector space models, and a compositional theory for grammatical types, for which we rely on the algebra of Pregroups, introduced by Lambek. This mathematical framework enables us to compute the meaning 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 Festschrift, special issue of Linguistic Analysis, 2010.


Alice
hates
Bob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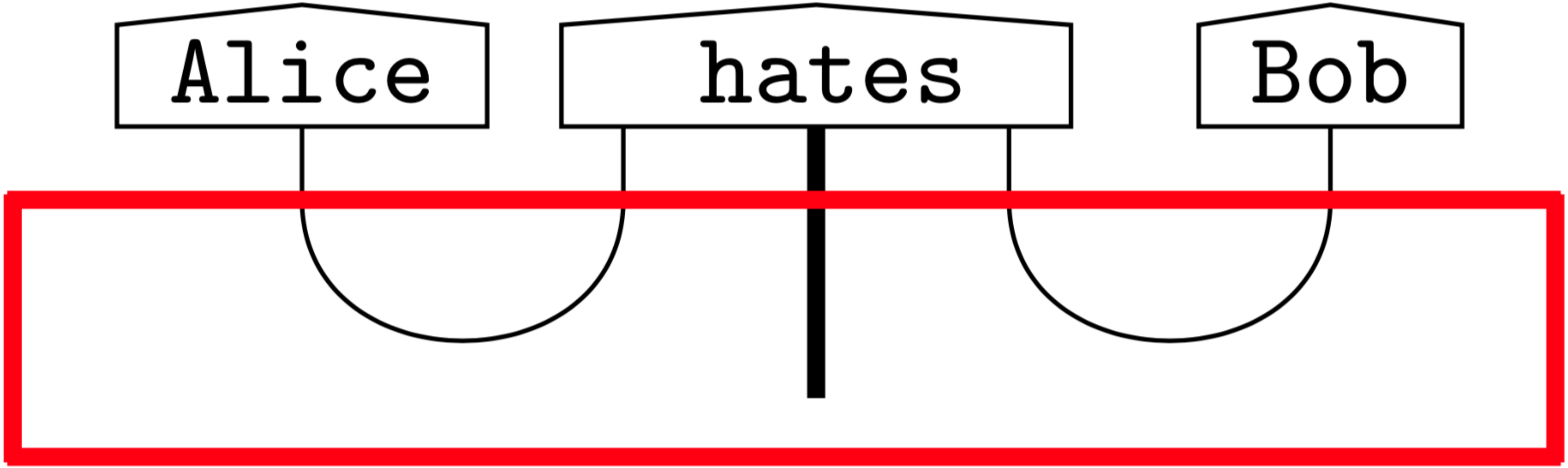
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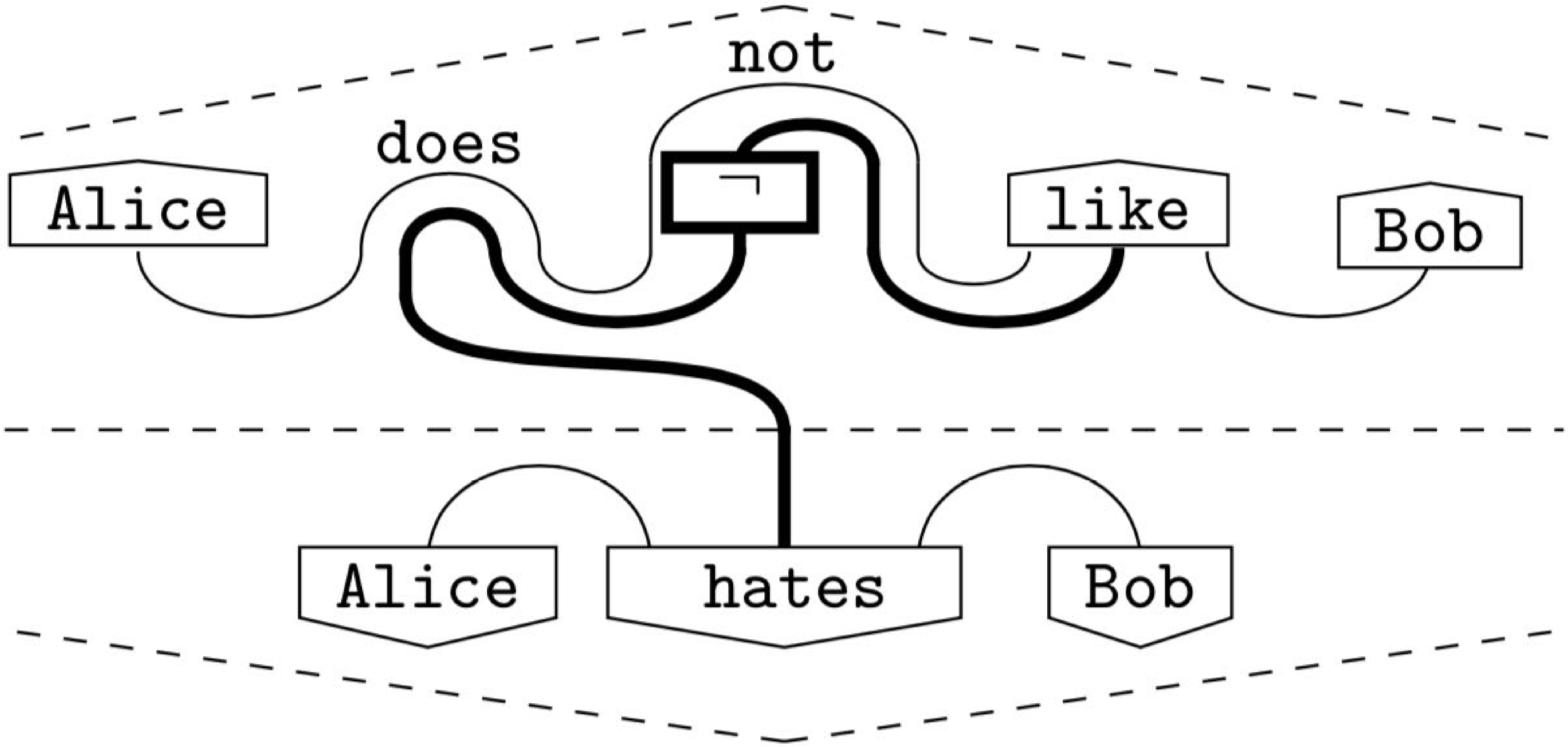

not
does
Alice
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like
Bob
Alice
hates
Bob

A mouthfull of spiders

arXiv.org > cs > arXiv:1404.5278

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Computer Science > Computation and Language

[Submitted on 21 Apr 2014]

The Frobenius anatomy of word meanings I: subject and object relative pronouns

Mehrnoosh Sadrzadeh, Stephen Clark, Bob Coecke

This paper develops a compositional vector-based semantics of subject and object relative pronouns within a categorical framework. Frobenius algebras are used to formalise the operations required to model the semantics of relative pronouns, including passing information between the relative clause and the modified noun phrase, as well as copying, combining, and discarding parts of the relative clause. We develop two instantiations of the abstract semantics, one based on a truth-theoretic approach and one based on corpus statistics.

arXiv.org > cs > arXiv:1904.03478v1

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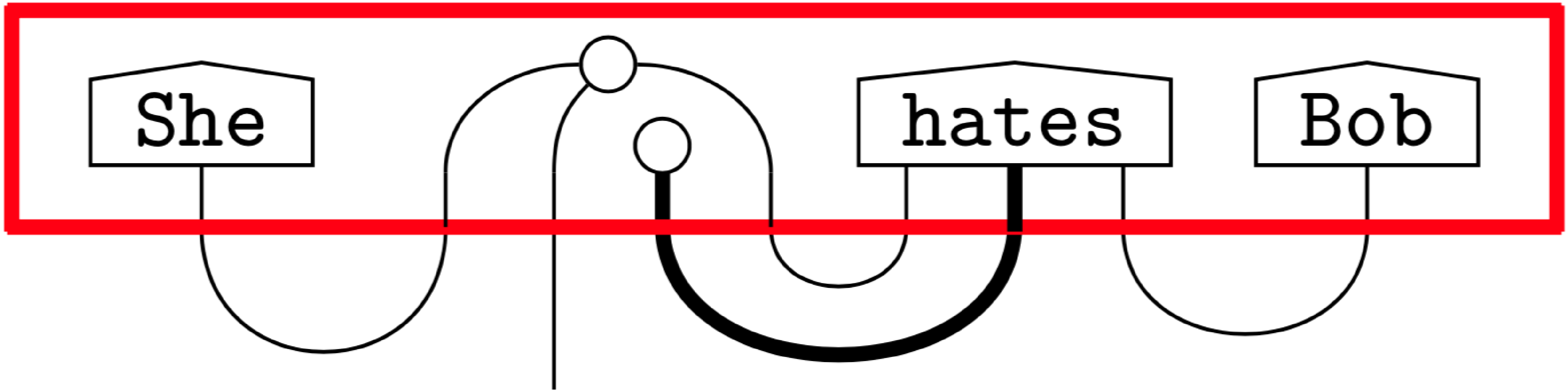
Computer Science > Computation and Language

[Submitted on 6 Apr 2019 (this version), **latest version 28 Feb 2020** *(v2)]*

The Mathematics of Text Structure

Bob Coecke

In previous work we gave a mathematical foundation, referred to as DisCoCat, for how words interact in a sentence in order to produce the meaning of that sentence. To do so, we exploited the perfect structural match of grammar and categories of meaning spaces. Here, we give a mathematical foundation, referred to as DisCoCirc, for how sentences interact in texts in order to produce the meaning of that text. We revisit DisCoCat: while in the latter all meanings are states (i.e. have no input), in DisCoCirc word meanings are types of which the state can evolve, and sentences are gates within a circuit which update the meaning of words. Like in DisCoCat, word meanings can live in a variety of spaces e.g. propositional, vectorial, or cognitive. The compositional structure are string diagrams representing information flows, and an entire text yields a single string diagram in which word meanings lift to the meaning of an entire text. While the developments in this paper are independent of a physical embodiment (cf. classical vs. quantum computing), both the compositional formalism and suggested meaning model are highly quantum-inspired, and implementation on a quantum computer would come with a range of benefits. We also praise Jim Lambek for his role in mathematical linguistics in general, and the development of the DisCo program more specifically.


She
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

SCIENTIFIC AMERICAN™

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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 —

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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arXiv.org > cs > arXiv:2102.12846

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Computer Science > Computation and Language

[Submitted on 25 Feb 2021]

QNLP in Practice: Running Compositional Models of Meaning on a Quantum Computer

Robin Lorenz, Anna Pearson, Konstantinos Meichanetzidis, Dimitri Kartsaklis, Bob Coecke

Quantum Natural Language Processing (QNLP) deals with the design and implementation of NLP models intended to be run on quantum hardware. In this paper, we present results on the first NLP experiments conducted on Noisy Intermediate-Scale Quantum (NISQ) computers for datasets of size >= 100 sentences. Exploiting the formal similarity of the compositional model of meaning by Coecke et al. (2010) with quantum theory, we create representations for sentences that have a natural mapping to quantum circuits. We use these representations to implement and successfully train two NLP models that solve simple sentence classification tasks on quantum hardware. We describe in detail the main principles, the process and challenges of these experiments, in a way accessible to NLP researchers, thus paving the way for practical Quantum Natural Language Processing.

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

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

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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.

arXiv.org > quant-ph > arXiv:2111.06741

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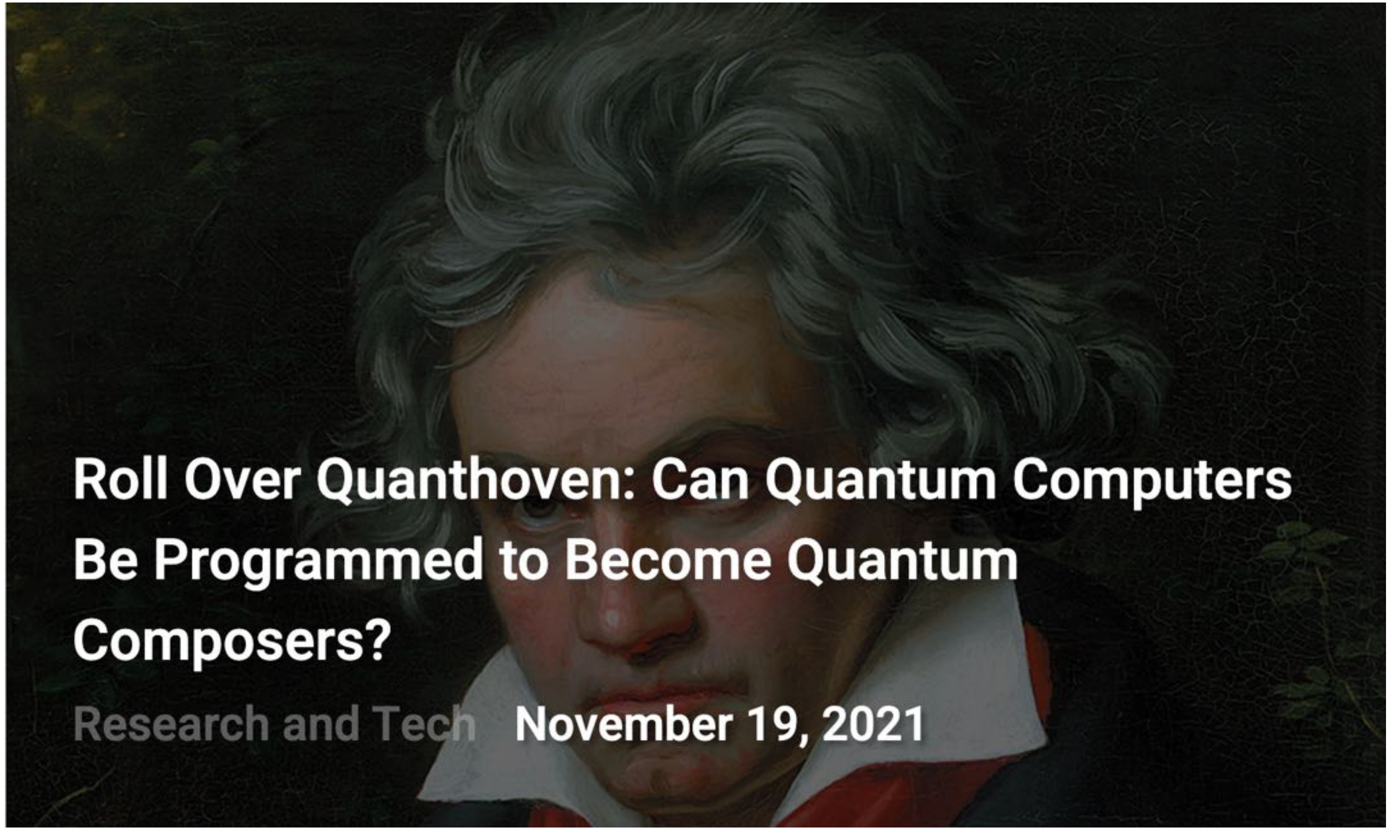
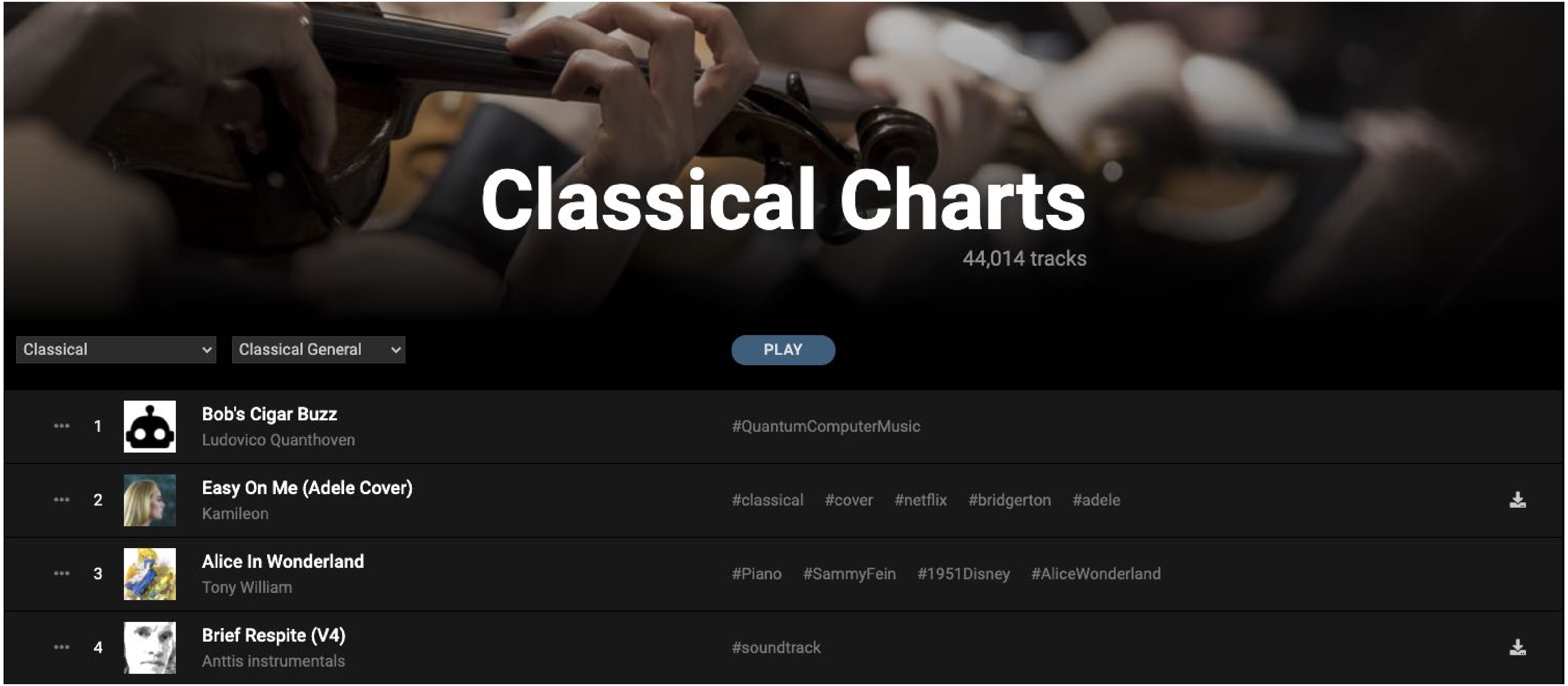
Quantum Physics

[Submitted on 10 Nov 2021]

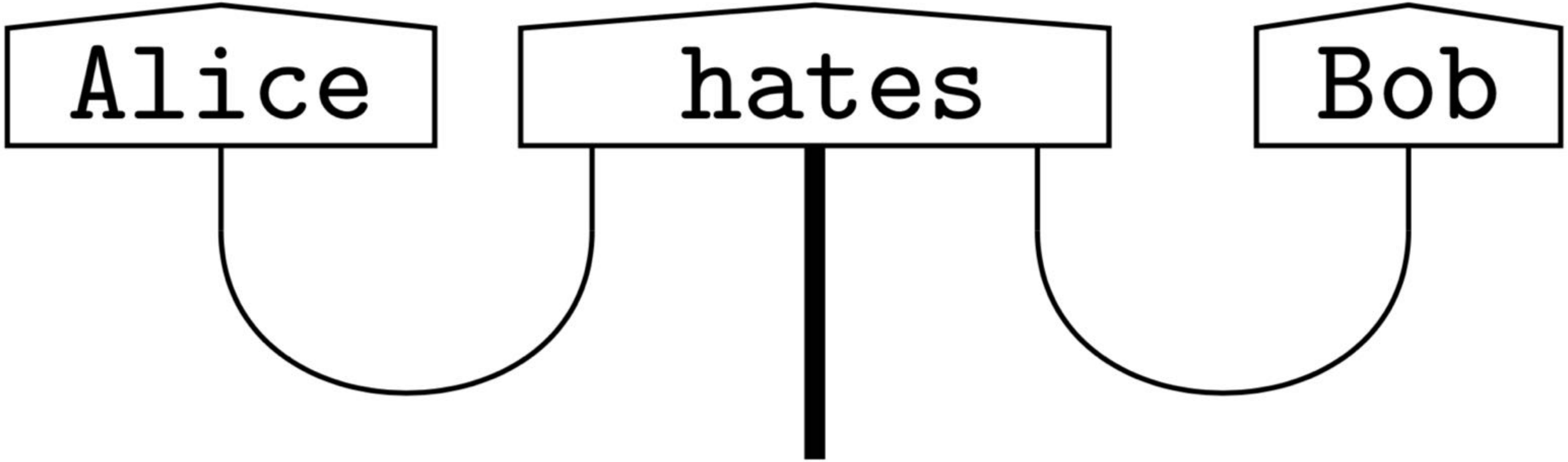
A Quantum Natural Language Processing Approach to Musical Intelligence

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




Classical Charts
44,014 tracks
Classical
Classical General
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
#soundtrack

inside lambeq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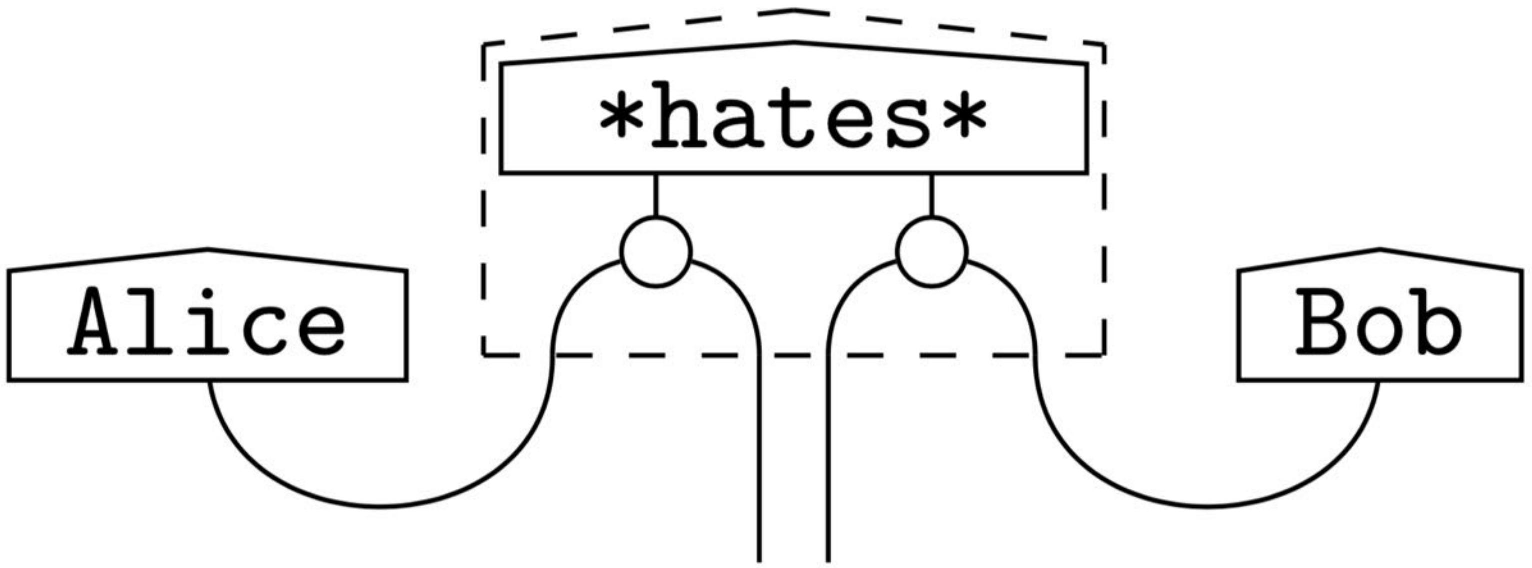
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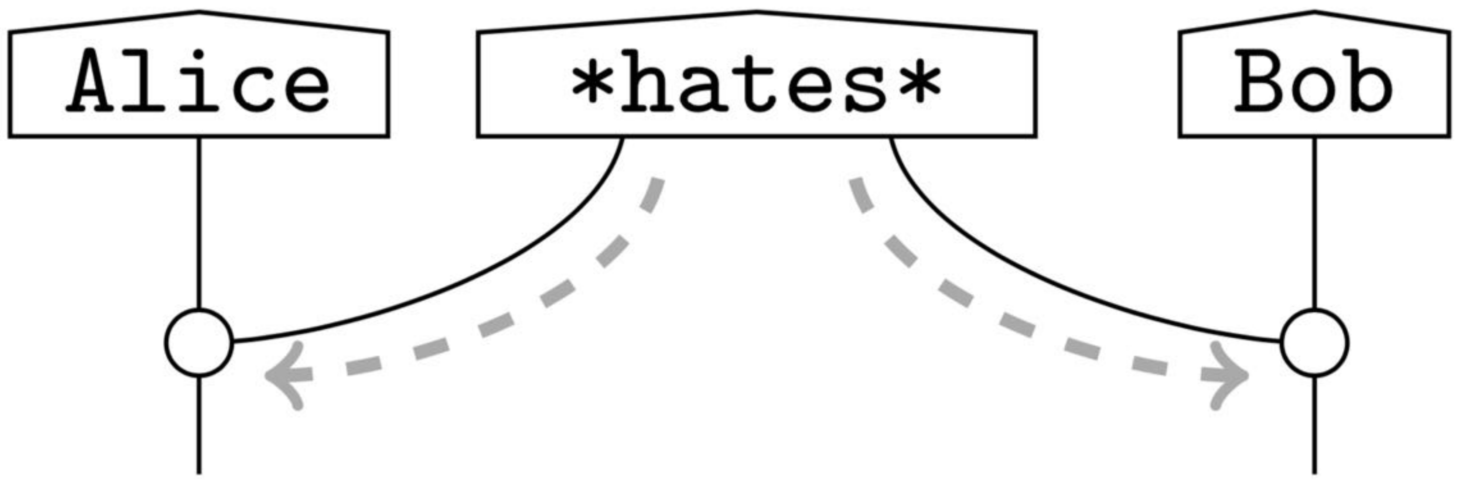
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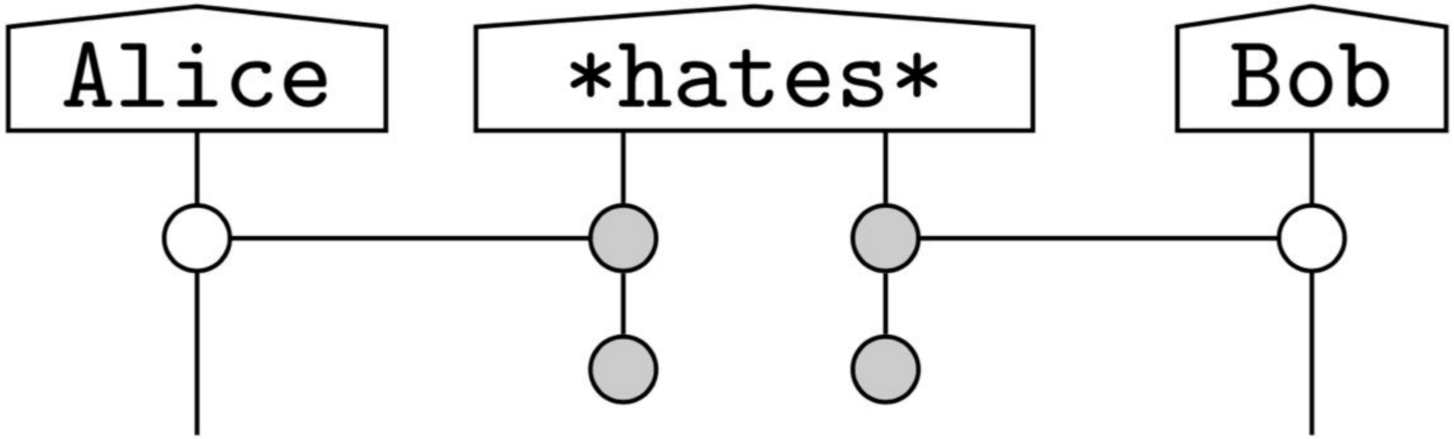
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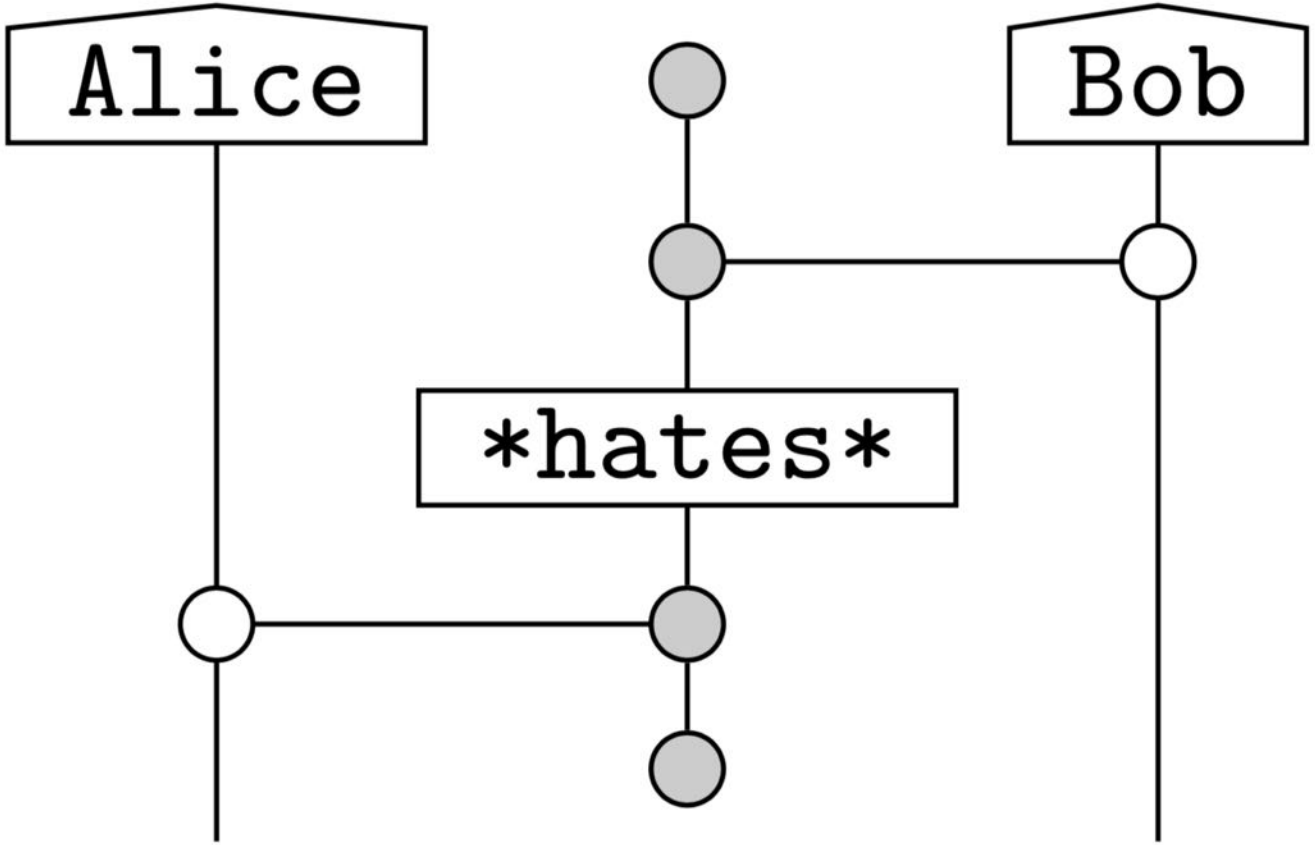
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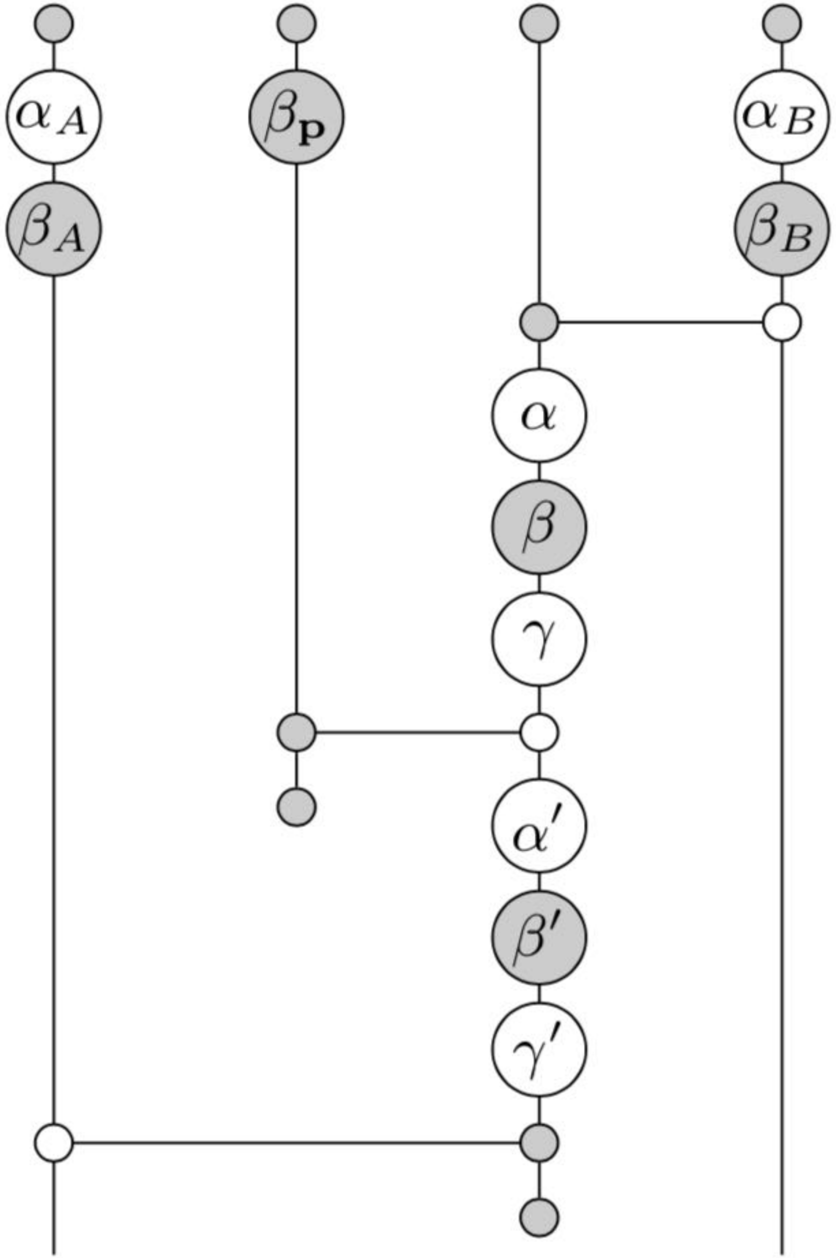
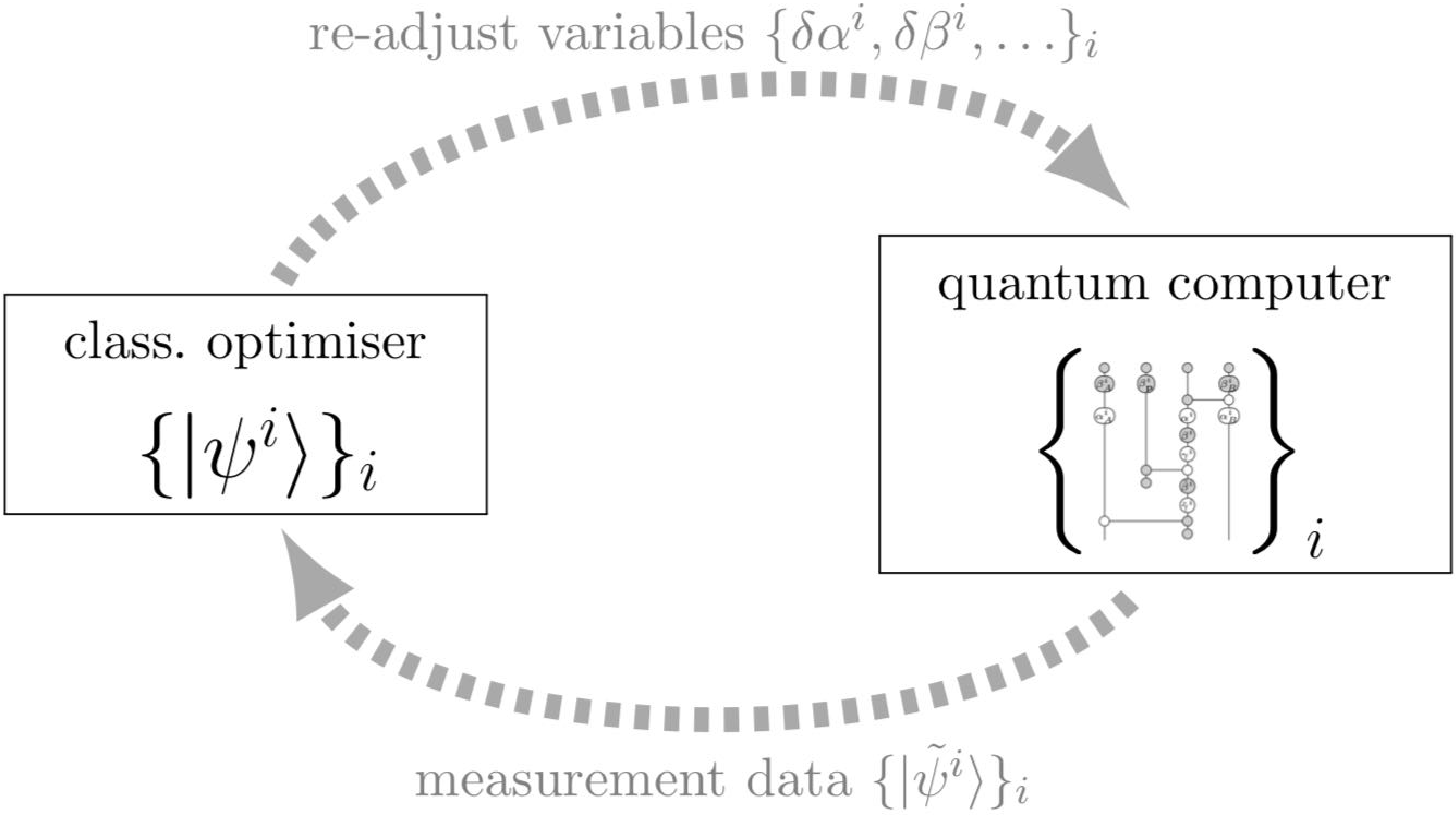


α_A
$\beta_{\mathbf{p}}$
α_B
β_A
β_B
α
β
γ
α'
β'
γ'



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

text circuits: a new theory of language

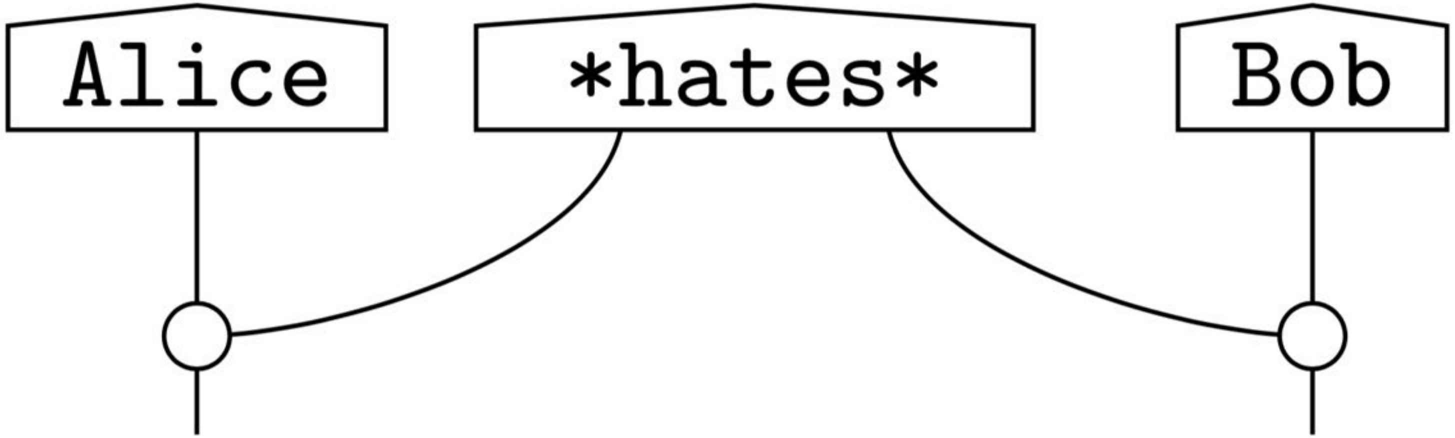
Computer Science > Computation and Language

[Submitted on 6 Apr 2019 (v1), last revised 28 Feb 2020 (this version, v2)]

The Mathematics of Text Structure

Bob Coecke

In previous work we gave a mathematical foundation, referred to as DisCoCat, for how words interact in a sentence in order to produce the meaning of that sentence. To do so, we exploited the perfect structural match of grammar and categories of meaning spaces. Here, we give a mathematical foundation, referred to as DisCoCirc, for how sentences interact in texts in order to produce the meaning of that text. First we revisit DisCoCat. While in DisCoCat all meanings are fixed as states (i.e. have no input), in DisCoCirc word meanings correspond to a type, or system, and the states of this system can evolve. Sentences are gates within a circuit which update the variable meanings of those words. Like in DisCoCat, word meanings can live in a variety of spaces e.g. propositional, vectorial, or cognitive. The compositional structure are string diagrams representing information flows, and an entire text yields a single string diagram in which word meanings lift to the meaning of an entire text. While the developments in this paper are independent of a physical embodiment (cf. classical vs. quantum computing), both the compositional formalism and suggested meaning model are highly quantum-inspired, and implementation on a quantum computer would come with a range of benefits. We also praise Jim Lambek for his role in mathematical linguistics in general, and the development of the DisCo program more specifically.


Alice
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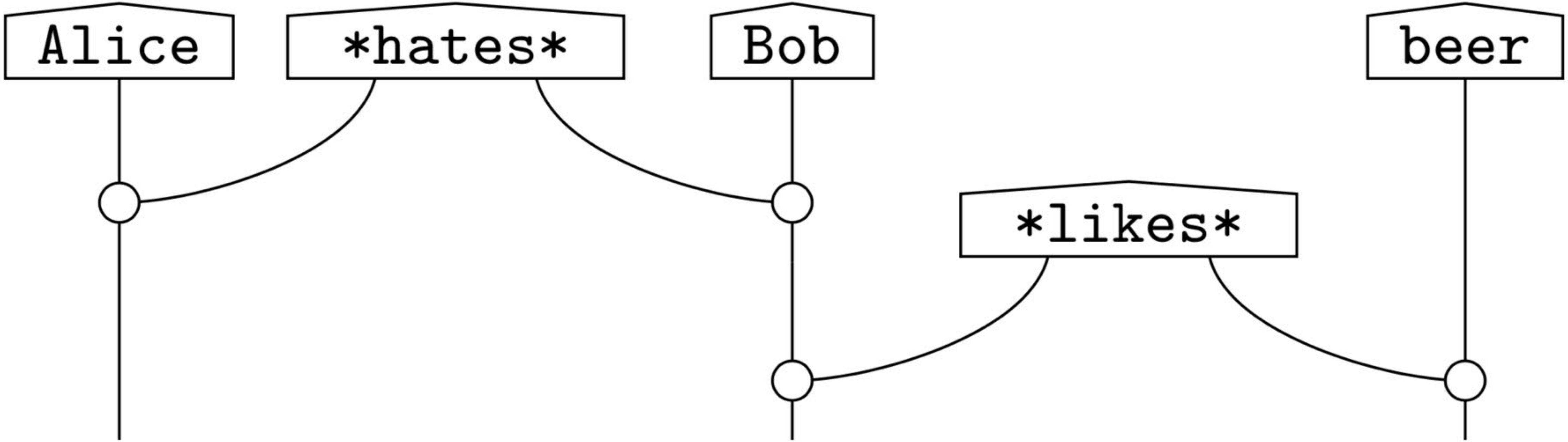

Alice
hates
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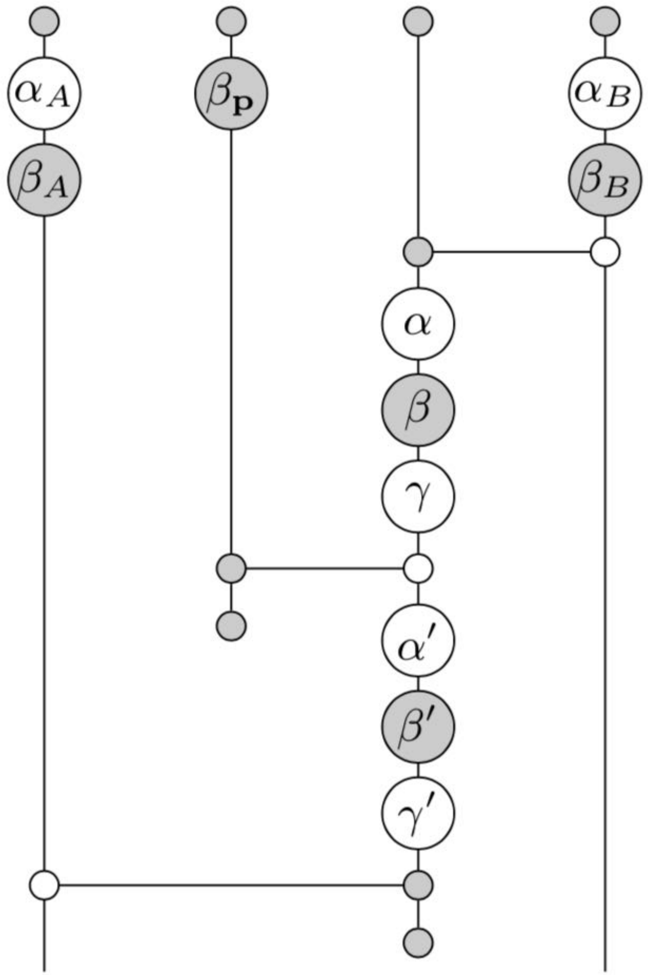
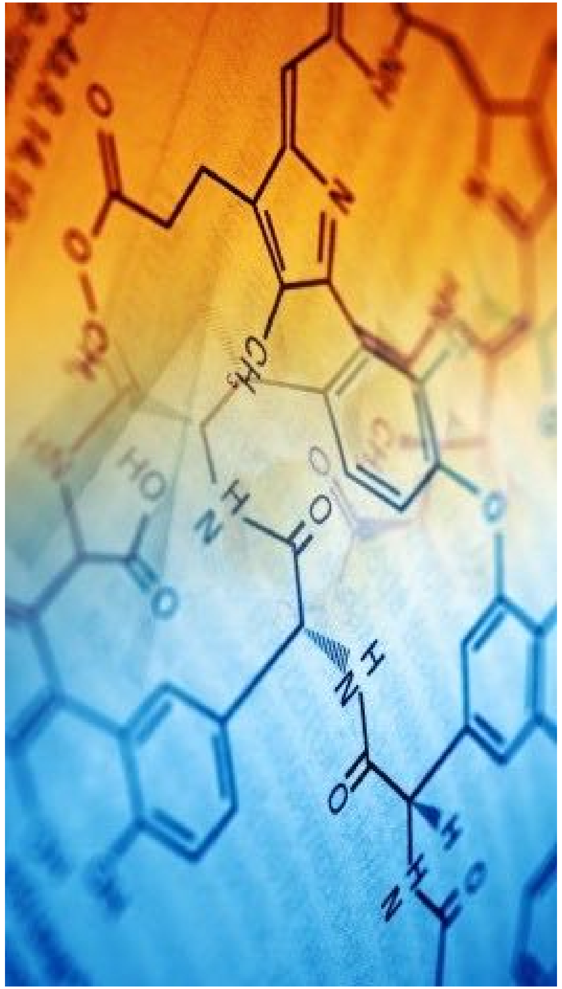
likes

text circuit (text2qcirc)



chemistry (Hamiltonian)



Quantinuum QNLP partnership with BBC, UCL

November 25, 2022

Quantinuum, integrated quantum computing company, has joined a consortium with University College London (UCL) and the BBC to explore the industrial relevance of quantum natural language processing (QNLP).

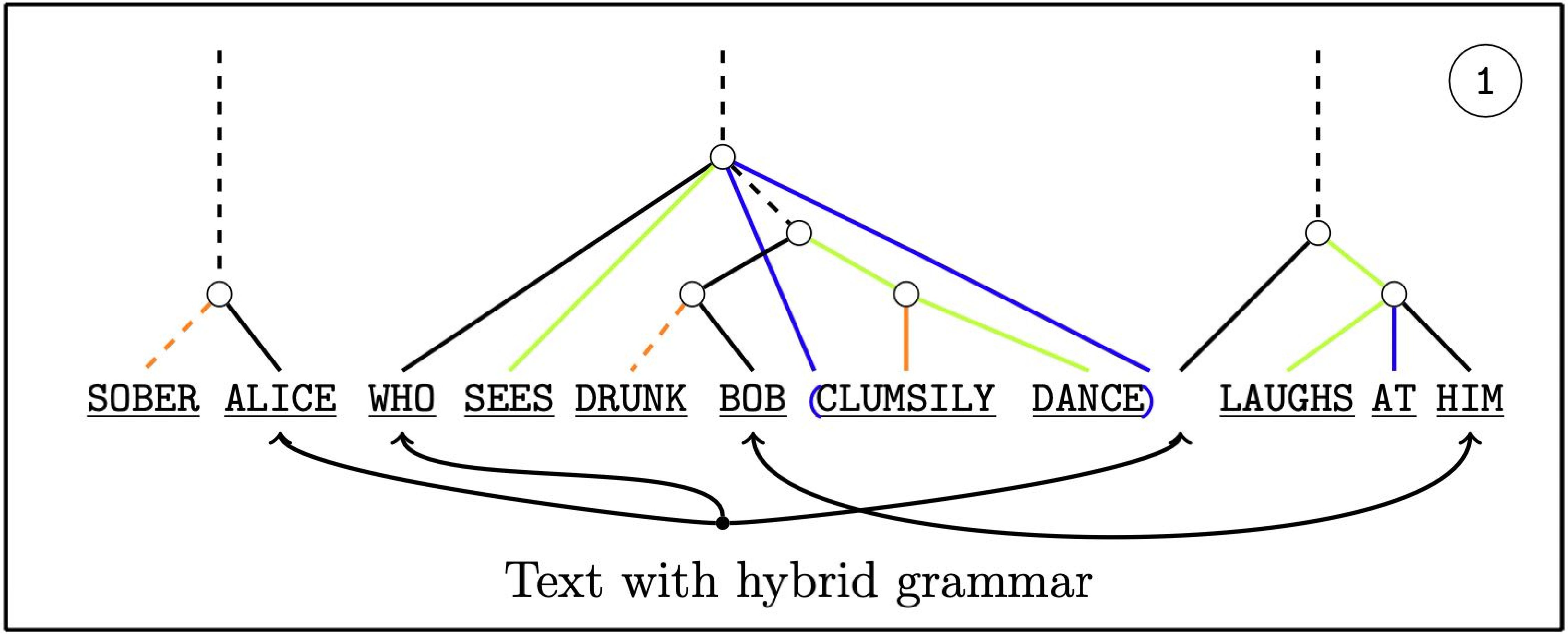
  

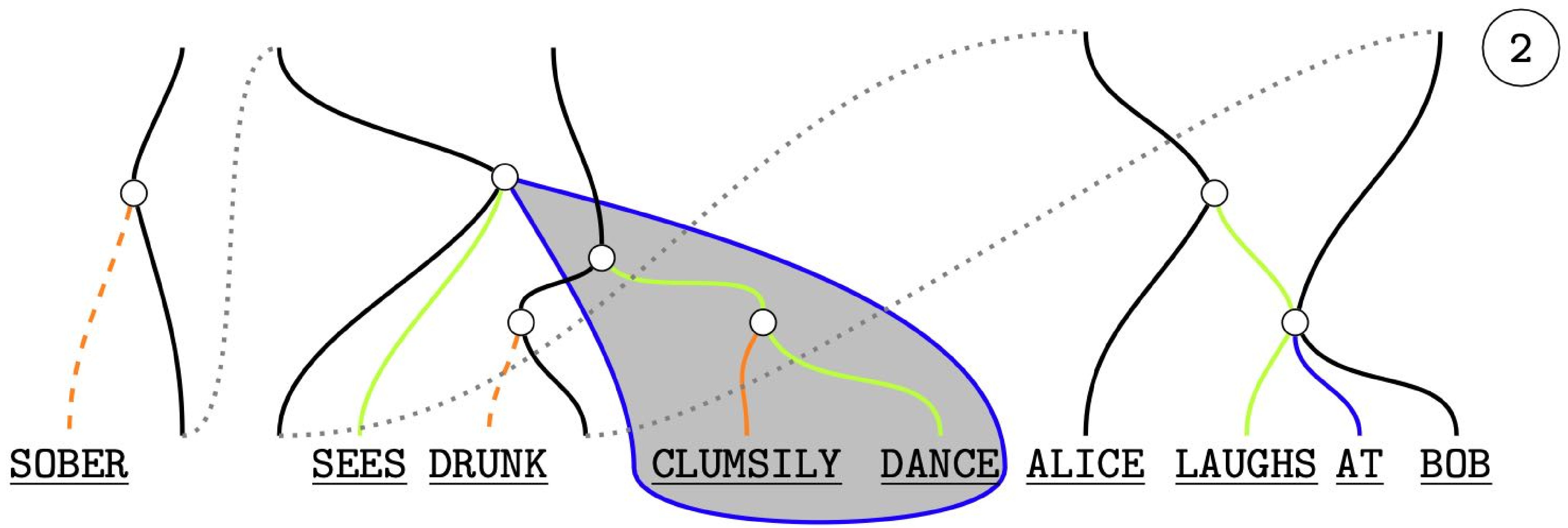
Distilling Text into Circuits

Vincent Wang-Maścianica[†‡], Jonathon Liu[†] and Bob Coecke[†]

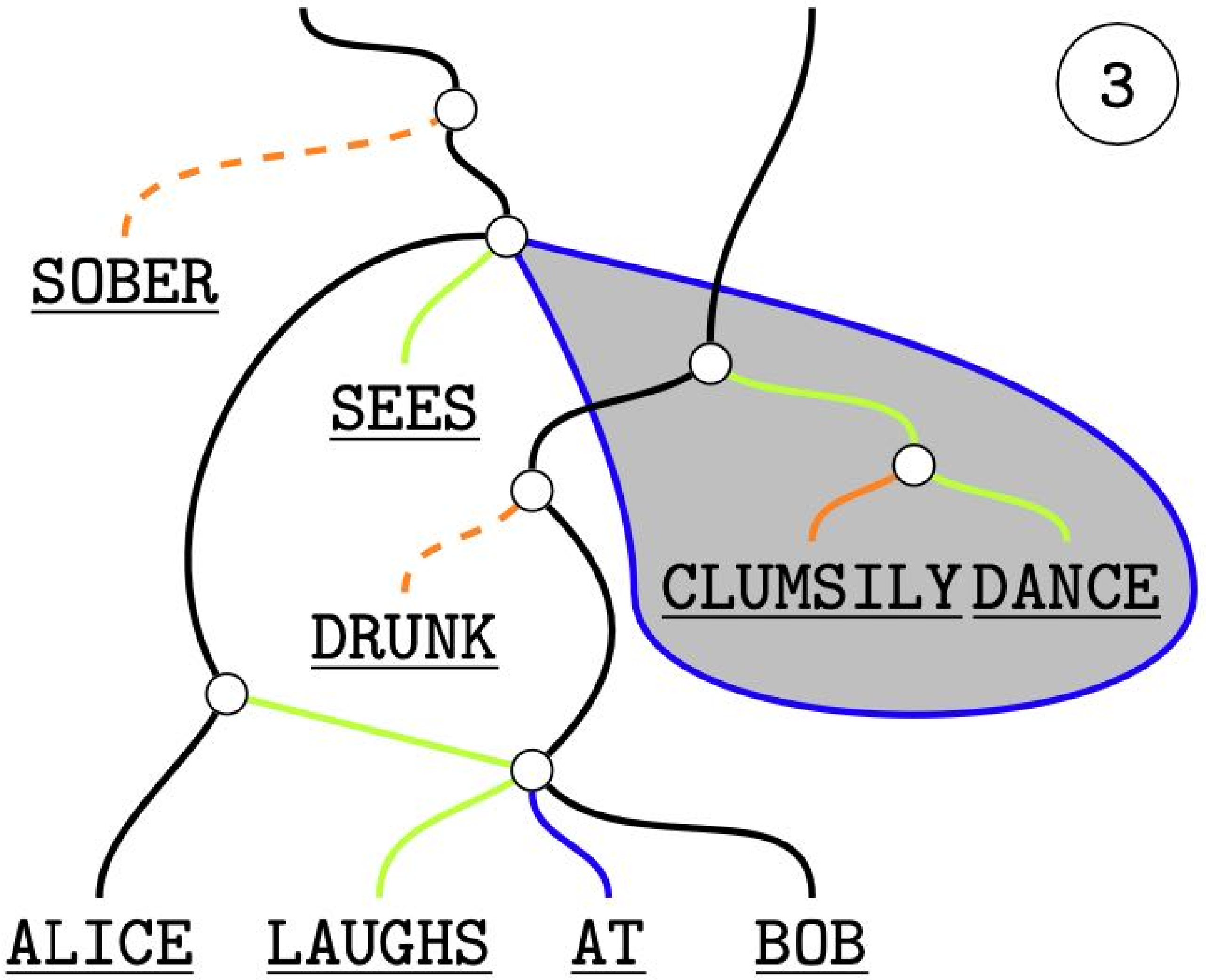
[†]Cambridge Quantum, Compositional Intelligence Team, Oxford
[‡]Oxford University, Department of Computer Science

February 23, 2022

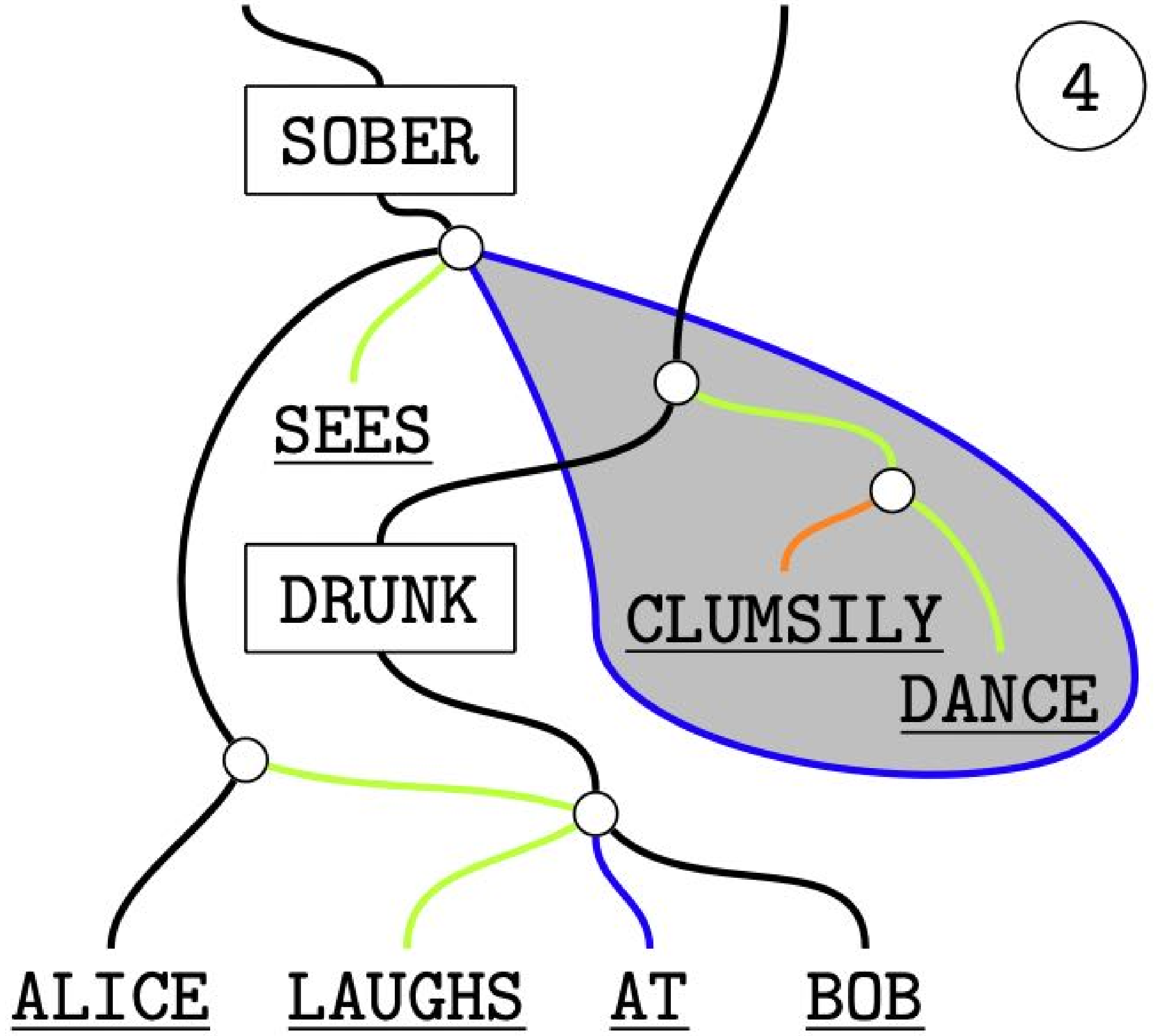

1
SOBER ALICE WHO SEES DRUNK BOB (CLUMSILY DANCE) LAUGHS AT HIM
Text with hybrid grammar



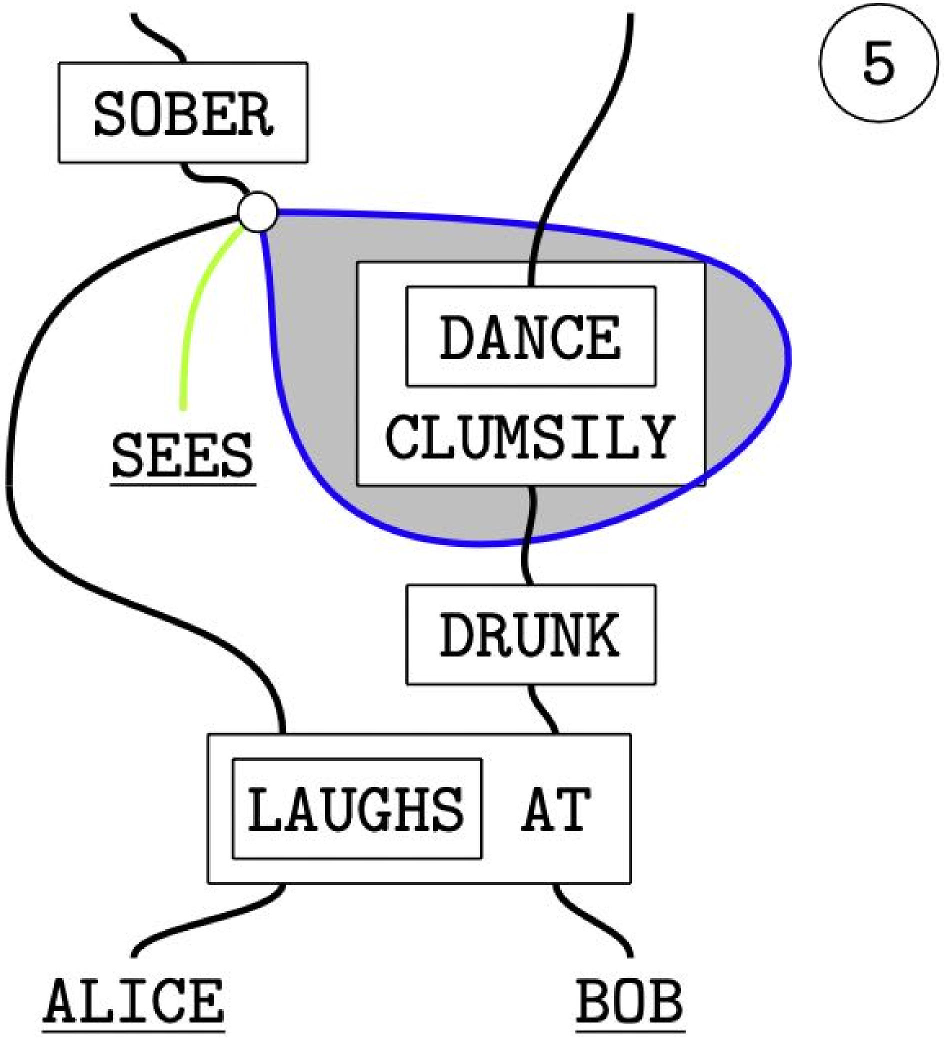
The same data, as a text diagram



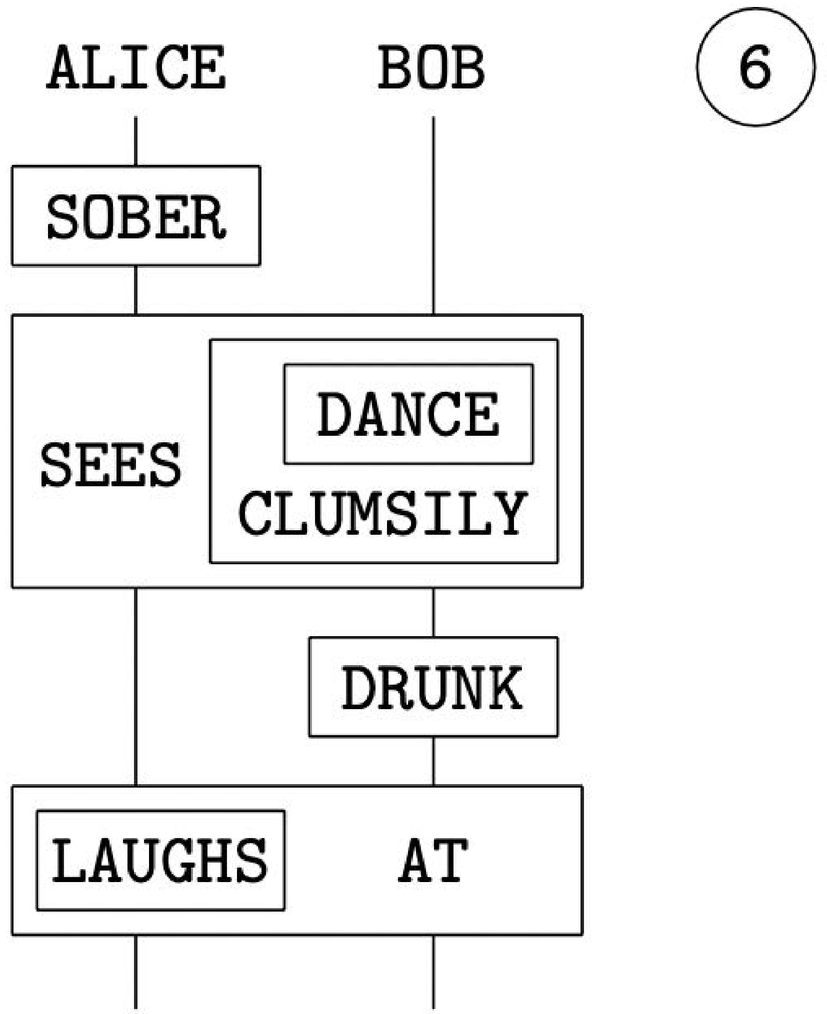
Rewrite links into composition



express as gates...

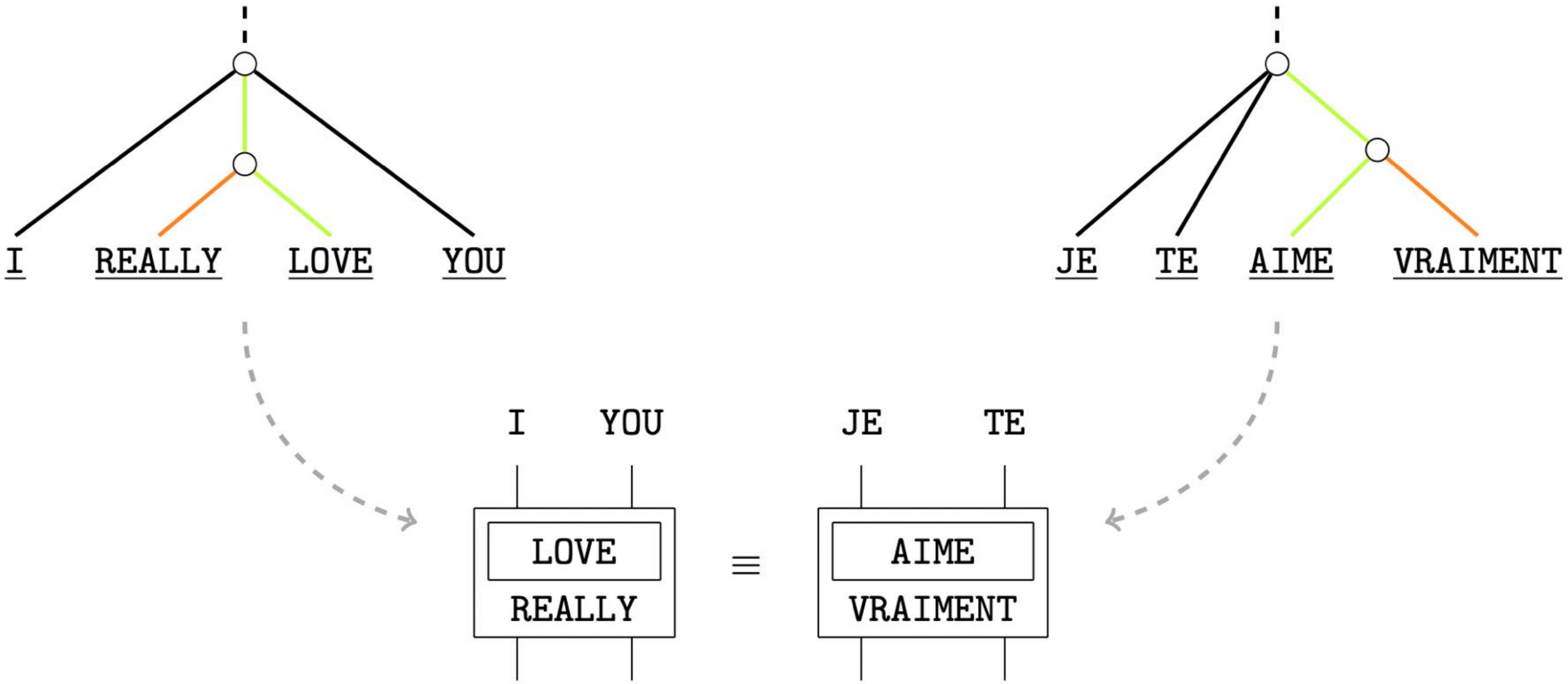


...and boxes...



...to get a circuit

Different languages become the same!

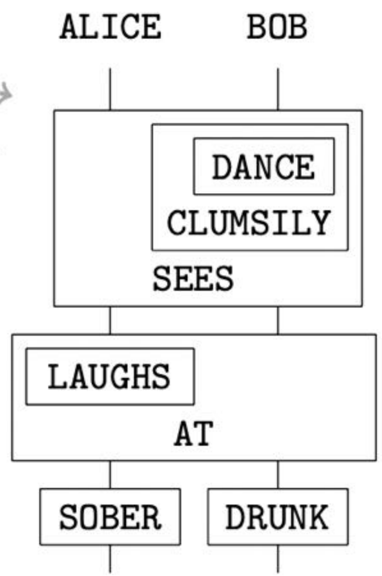


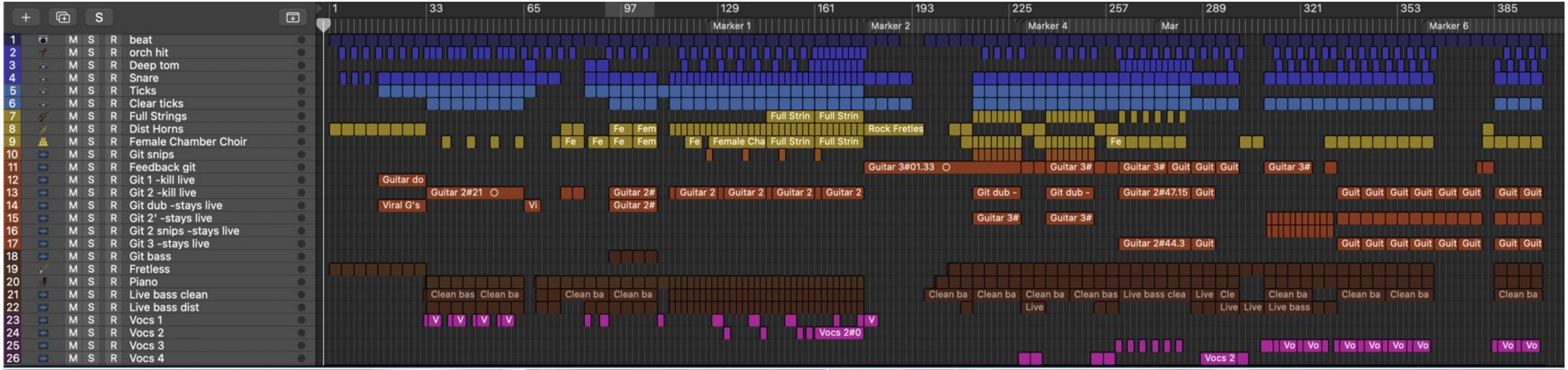
Different styles become the same!

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.




1
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289
321
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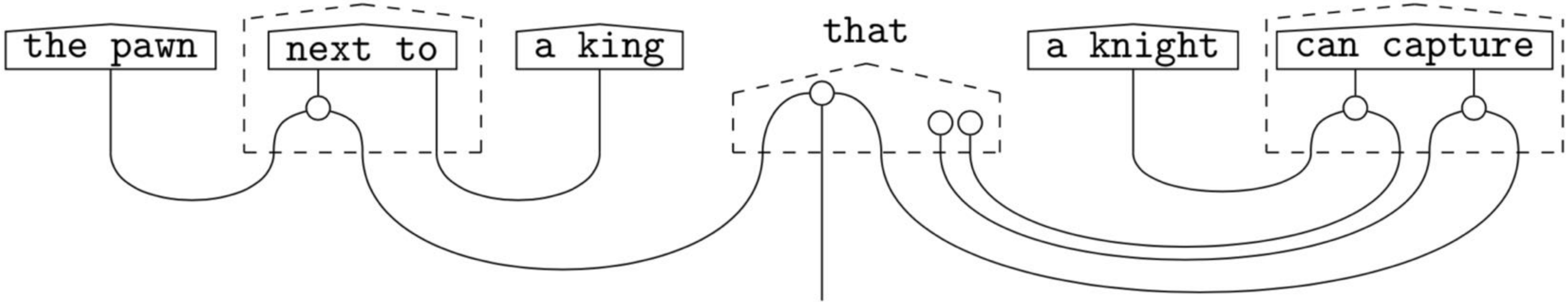
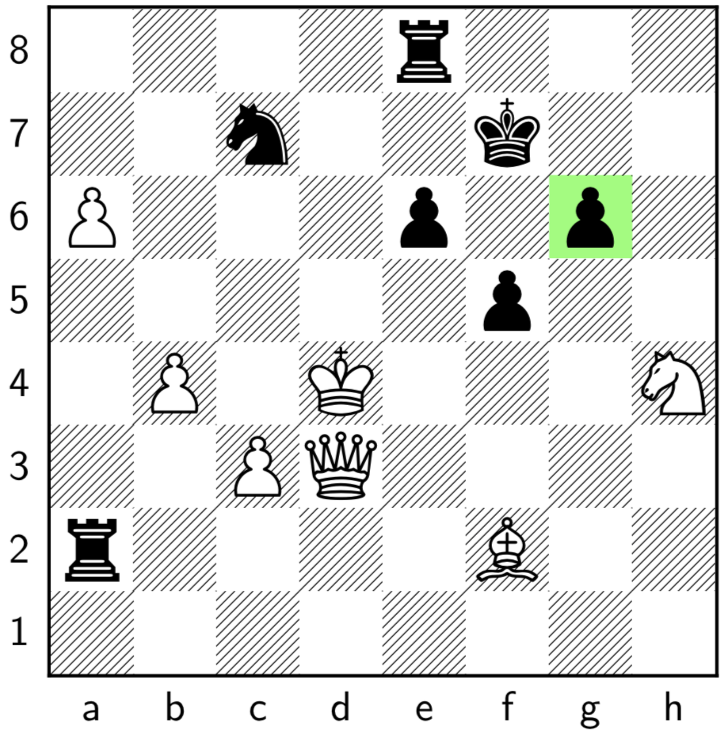
385
Marker 1
Marker 2
Marker 4
Mar
Marker 6
1 M S R beat
2 M S R orch hit
3 M S R Deep tom
4 M S R Snare
5 M S R Ticks
6 M S R Clear ticks
7 M S R Full Strings
8 M S R Dist Horns
9 M S R Female Chamber Choir
10 M S R Git snips
11 M S R Feedback git
12 M S R Git 1 -kill live
13 M S R Git 2 -kill live
14 M S R Git dub -stays live
15 M S R Git 2' -stays live
16 M S R Git 2 snips -stays live
17 M S R Git 3 -stays live
18 M S R Git bass
19 M S R Fretless
20 M S R Piano
21 M S R Live bass clean
22 M S R Live bass dist
23 M S R Vocs 1
24 M S R Vocs 2
25 M S R Vocs 3
26 M S R Vocs 4


Matty Hoban
Chris Heunen
Me
Aleks Kissinger
Ross Duncan


Me
Konstantinos
Meichanedzidis
Oxford Office
Builder

compositional intelligence


the pawn
next to
a king
that
a knight
can capture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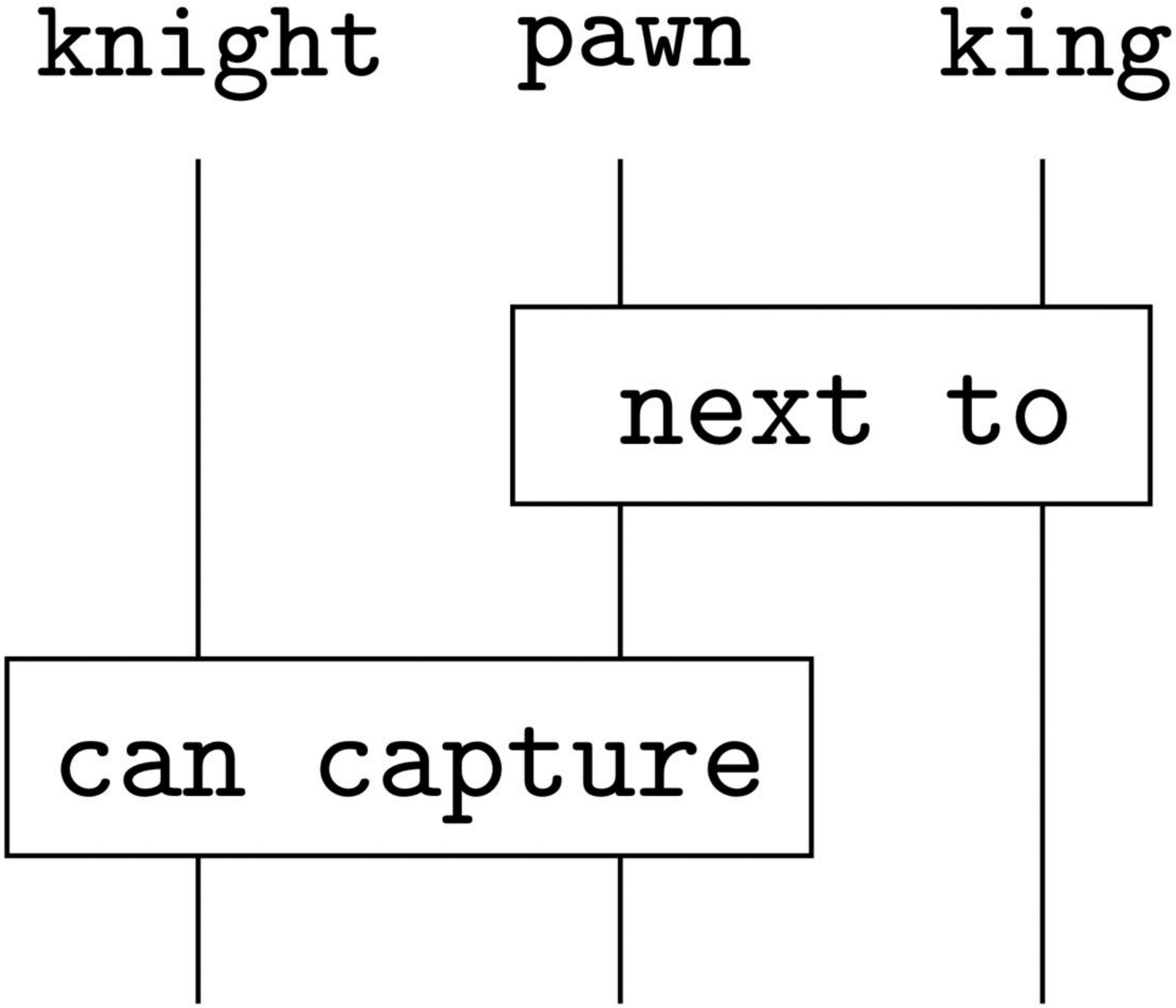
knight
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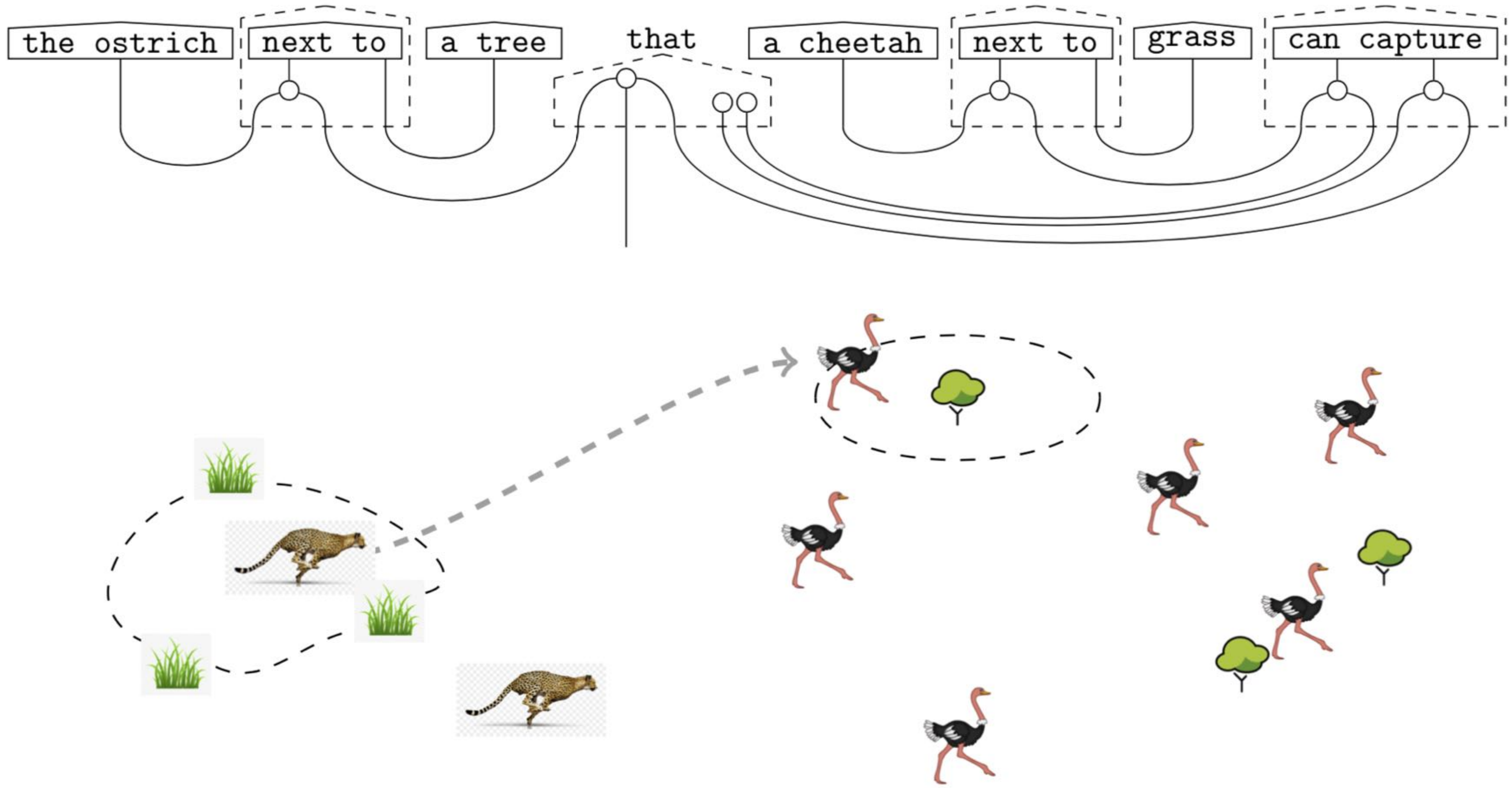
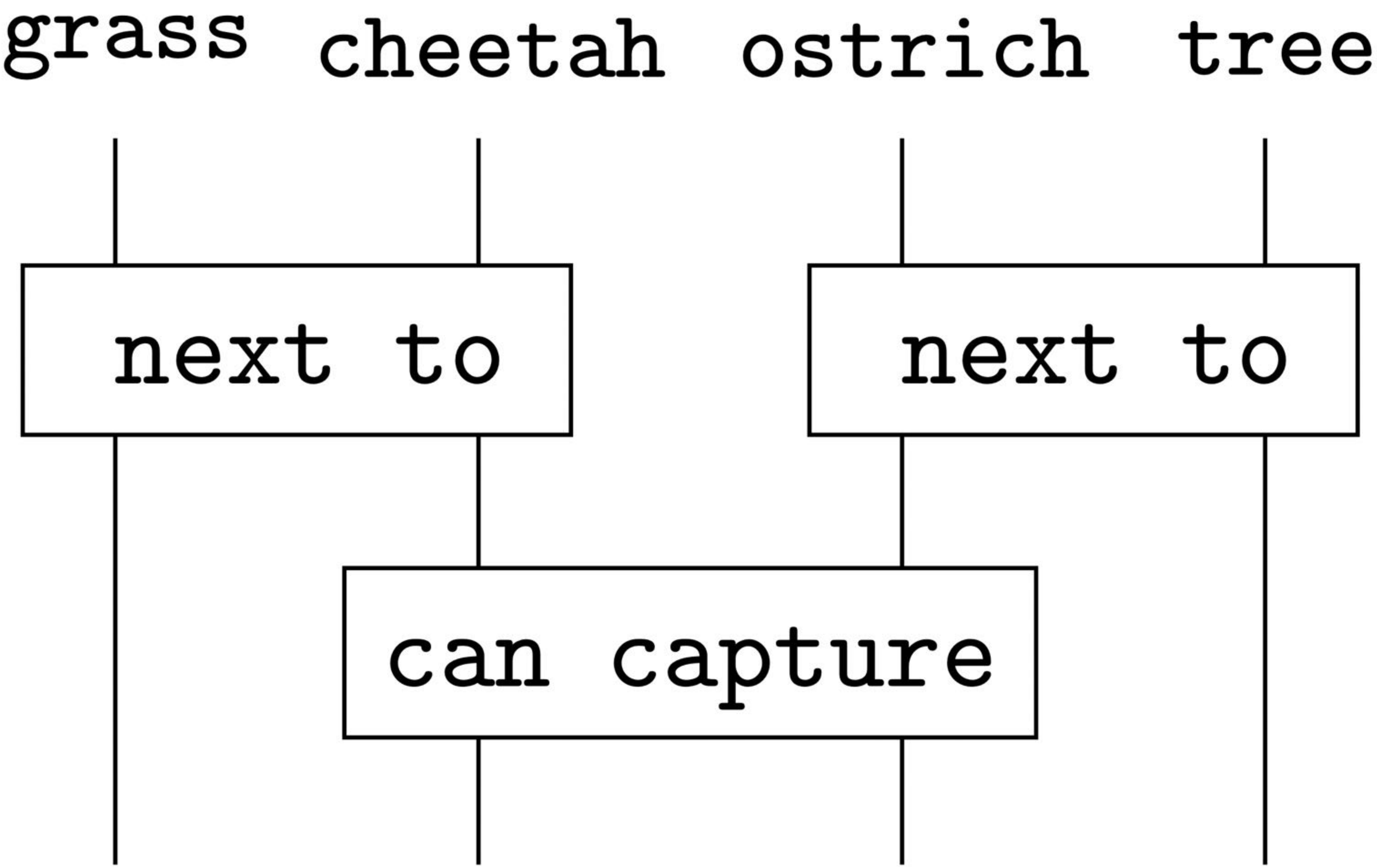
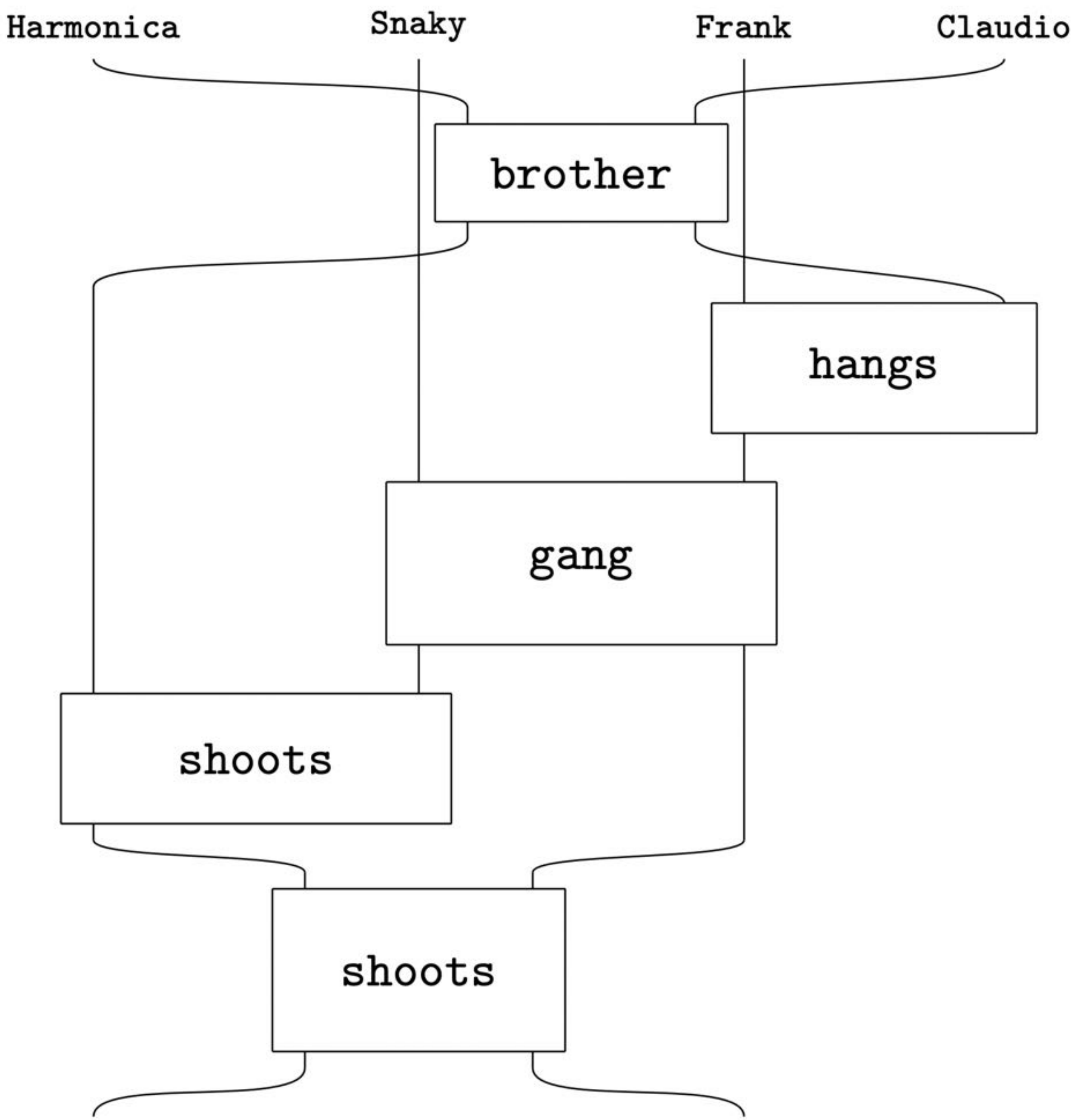

the ostrich
next to
a tree
that
a cheetah
next to
grass
can capture


grass
cheetah
ostrich
tree
next to
next to
can capture



Harmonica
Snaky
Frank
Claudio
brother
hangs
gang
shoots
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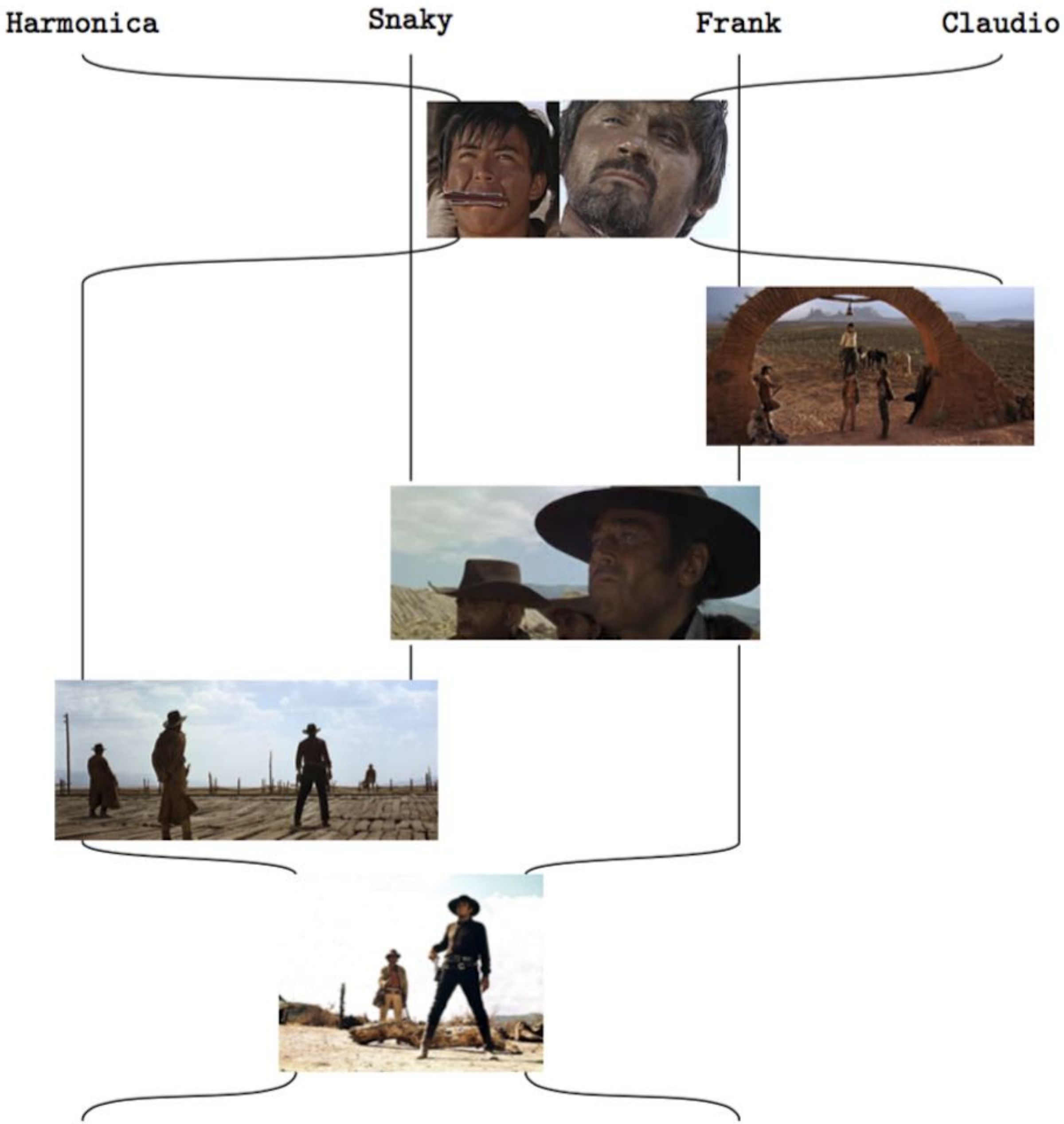
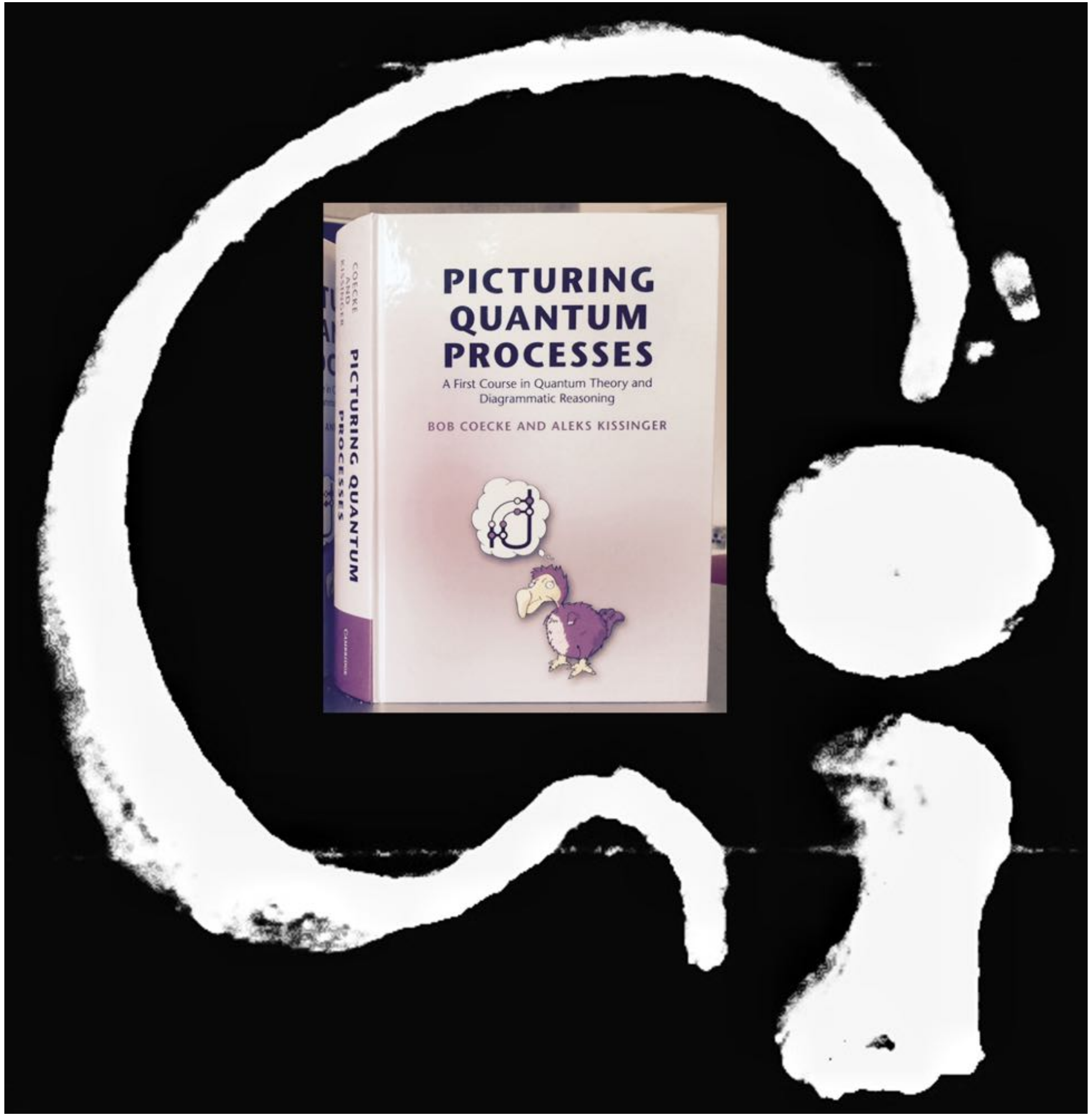

Harmonica
Snaky
Frank
Claudio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A First Course in Quantum Theory and Diagrammatic Reasoning
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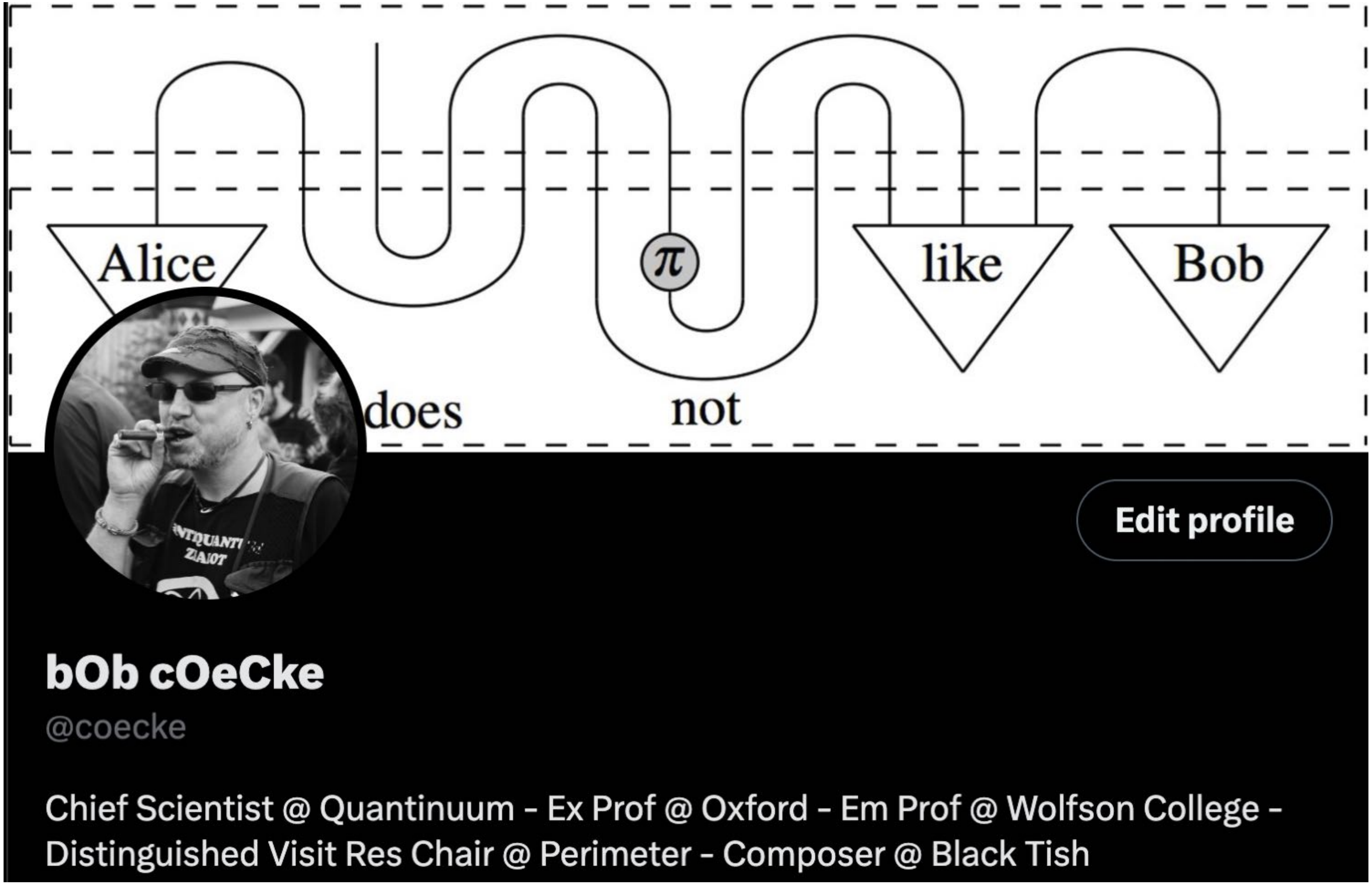
Alice
does
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Bob
Edit profile
bOb cOeCke
@coecke
Chief Scientist @ Quantinuum - Ex Prof @ Oxford - Em Prof @ Wolfson College -
Distinguished Visit Res Chair @ Perimeter - Composer @ Black Tish