

The STRANGE WORLD *of the* FUTURE

COGNITIVE
COMPUTING

Chris Welty



**We are now no longer the knights
who say... IBM**

**(I joined Google
Research in Sept.)**



Brief Personal History

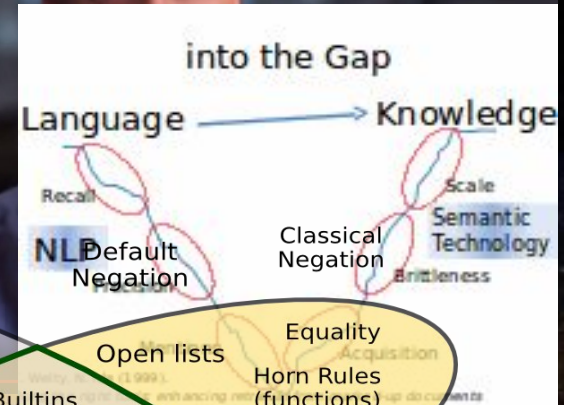
#originalwatsonsteam

(Watson on *Jeopardy!*)

Natural Language Processing

Semantic Web

Ontology



Harith Alani, Lolama Kagal, Achille Fokoue, Paul Groth, Chris Bommann, Josiane Xavier Parreira, Lora Aroyo, Natasha Noy, Chris Welty, Krzysztof Janowicz (Eds.)

UNCS 8219 The Semantic Web – ISWC 2013

12th International Semantic Web Conference Sydney, NSW, Australia, October 2013 Proceedings, Part II

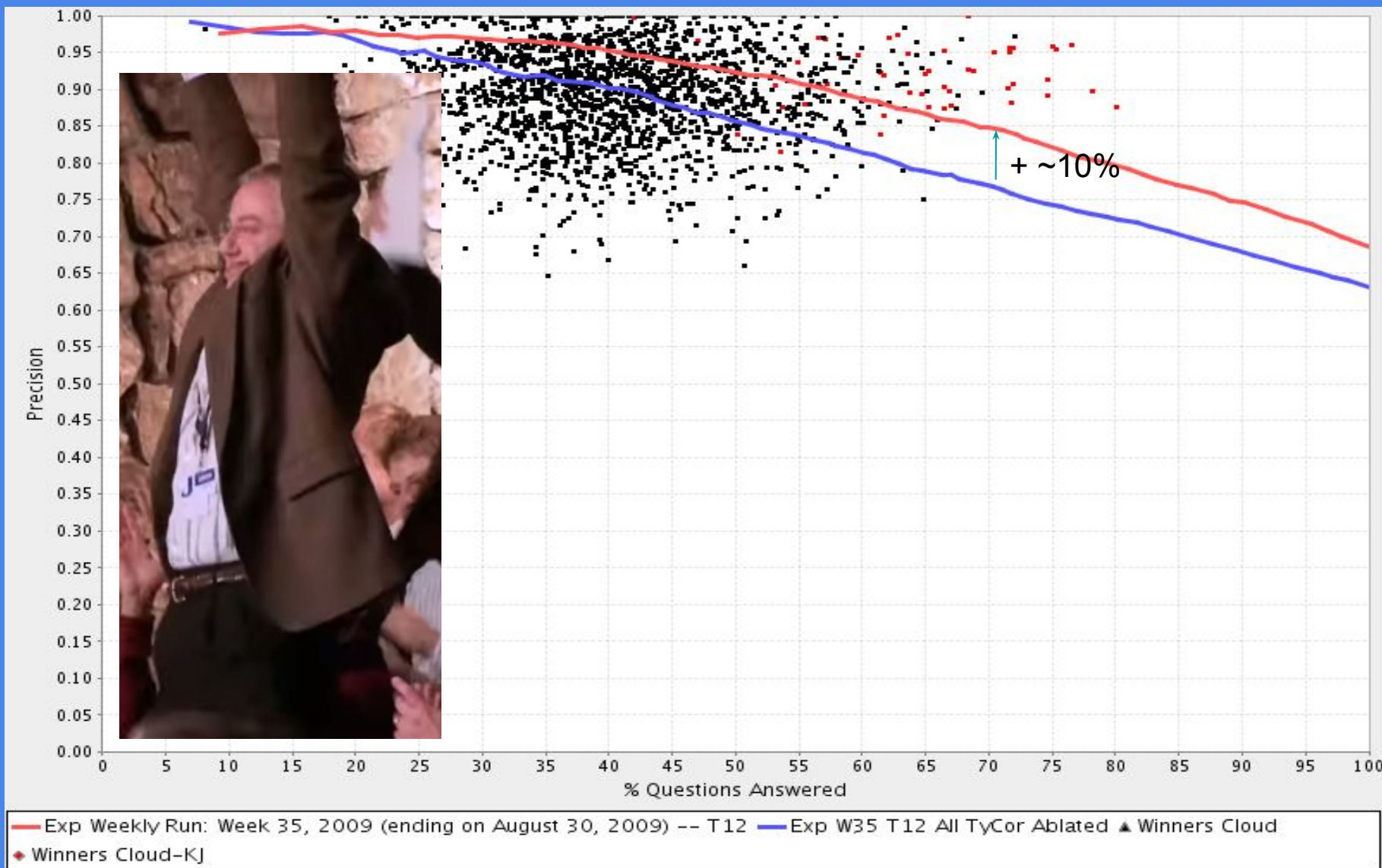


Recurring Personal Theme

**Using explicit semantics
to improve performance**



Explicit Semantics in Watson



ἰ ἄμαρ πρεστὰρ ἀέν

I amar prestar aen
The world has changed



WWW 2012

Keynote

- A new software paradigm has emerged
 - Increasingly, computational tasks require inexact solutions that combine multiple methods in unpredictable ways
- Knowledge is not the destination
 - Watson does not answer a question by translating natural language input into formally represented knowledge and simply running queries against this knowledge
- Machine intelligence is *not* human intelligence
 - The difference is most notable in the mistakes they make

A new software paradigm emerging (not that we invented it)



WWW 2012
Keynote

- The basic Watson computation is Hypothesis Scoring
 - How well does an answer fit into a question?
- More than 100 different Hypothesis scoring software components
 - No single scoring component does the whole job
 - Many of them do very similar jobs
 - 12 typing components, 8 passage alignment components, 10 n-gram components, ...
- These components are not integrated with each other beyond that they each produce a score for each hypothesis
- A machine learning algorithm learns how to combine them to produce a final score
- The development methodology involved an incremental approach of producing stable baseline systems and testing changes with “follow-ons”
- Changes that improve performance according to our metrics are accepted into the next stable baseline

Cognitive Computing: Three elements

EXPANDS

EXPANDS human cognition, makes the jobs we do easier, like a *cognitive prosthesis*, especially when dealing with processing massive data, or data that requires human interpretation

LEARNS as you use it – most machine errors are easy for a human to detect, and we can instrument usage of systems to better understand the system and the problem it solves

LEARNS

INTERACTS

INTERACTS naturally. We need to bring machines closer to their users, we have adapted ourselves enough to them, they should understand natural language, spoken or written, be able to process images and videos. These *simple* human problems are extremely complex for machines, but are hallmarks of a new computing era.

A person wearing a full-body silver robot suit is standing against a dark, starry background. A white circle highlights the human head inside the suit's helmet.

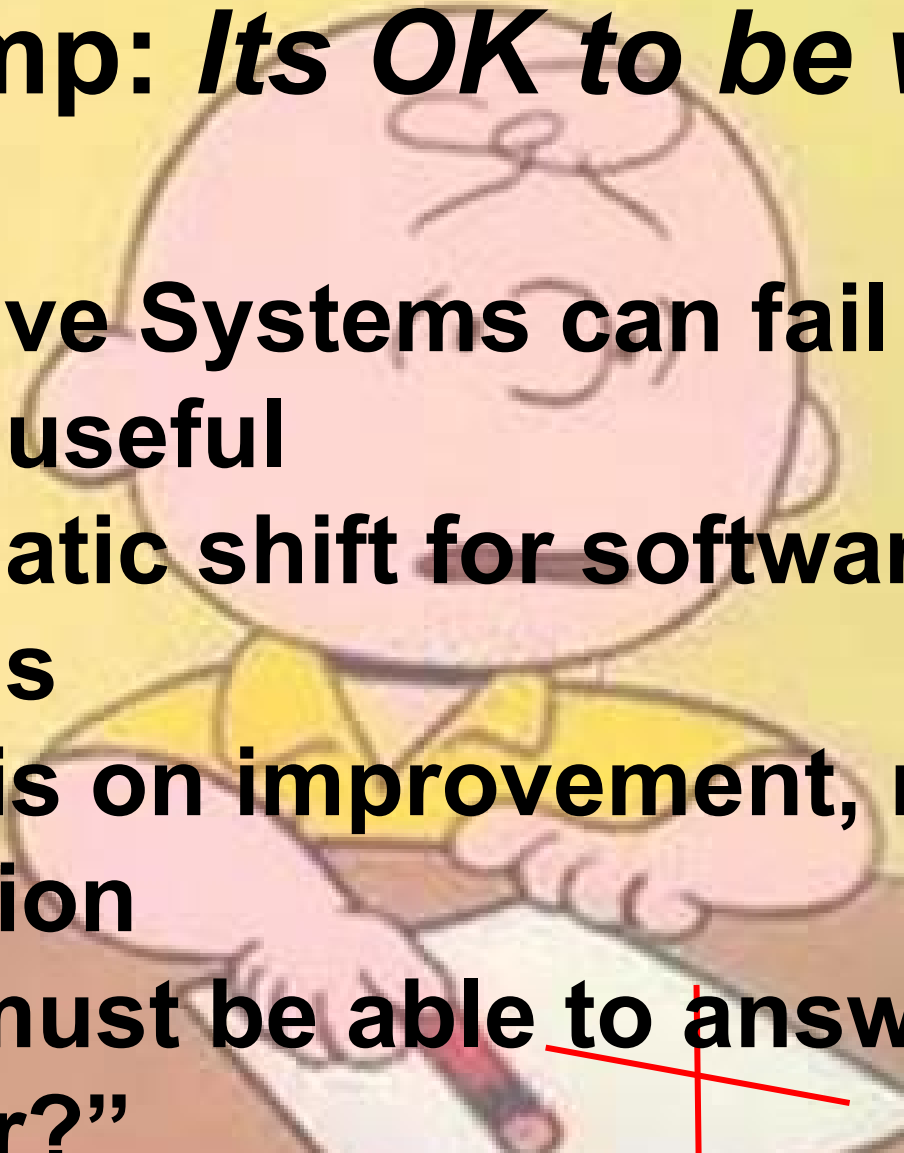
COGNITIVE COMPUTING

and the Future!

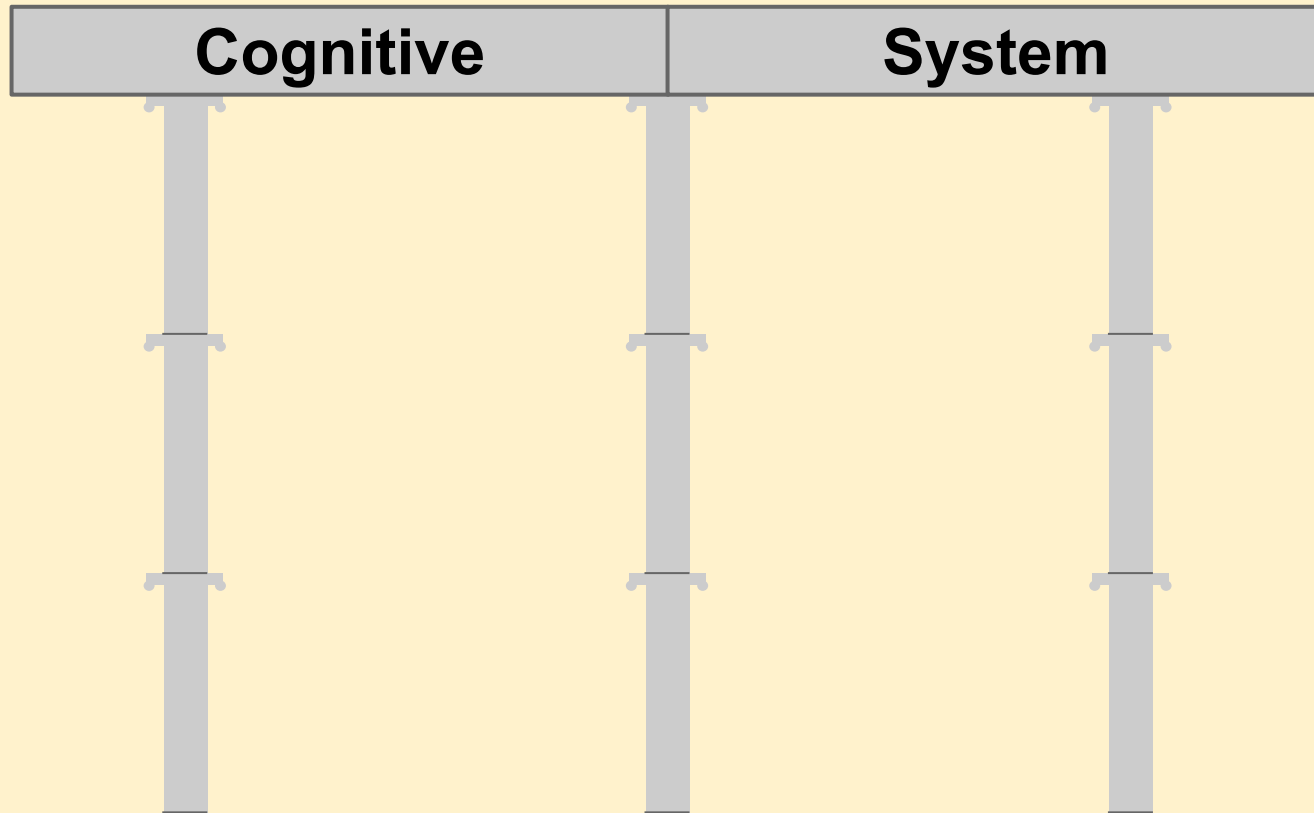
Introducing....

The
Cognitive
Systems
Engineer
(CSE)

CogComp: *Its OK to be wrong!*

- **Cognitive Systems can fail and still be useful**
 - **A dramatic shift for software systems**
 - **Focus is on improvement, not perfection**
 - **CSEs must be able to answer, “Is it better?”**
- 
- A cartoon illustration of a man with a large head, wearing a yellow shirt, sitting at a desk and holding a pen, looking thoughtful. The background is a light yellow gradient.

The 9 pillars of cognitive systems engineering



Measure, measure, measure

- Devise (& believe) a metric
 - e.g. % correct at 70% answered, or % correct at .5 confidence, or # correct at .8 confidence
- Establish baseline performance
 - new development is only added when it *improves* performance
- If your cognitive system reaches above .8 then probably your metric, data, or truth is inadequate



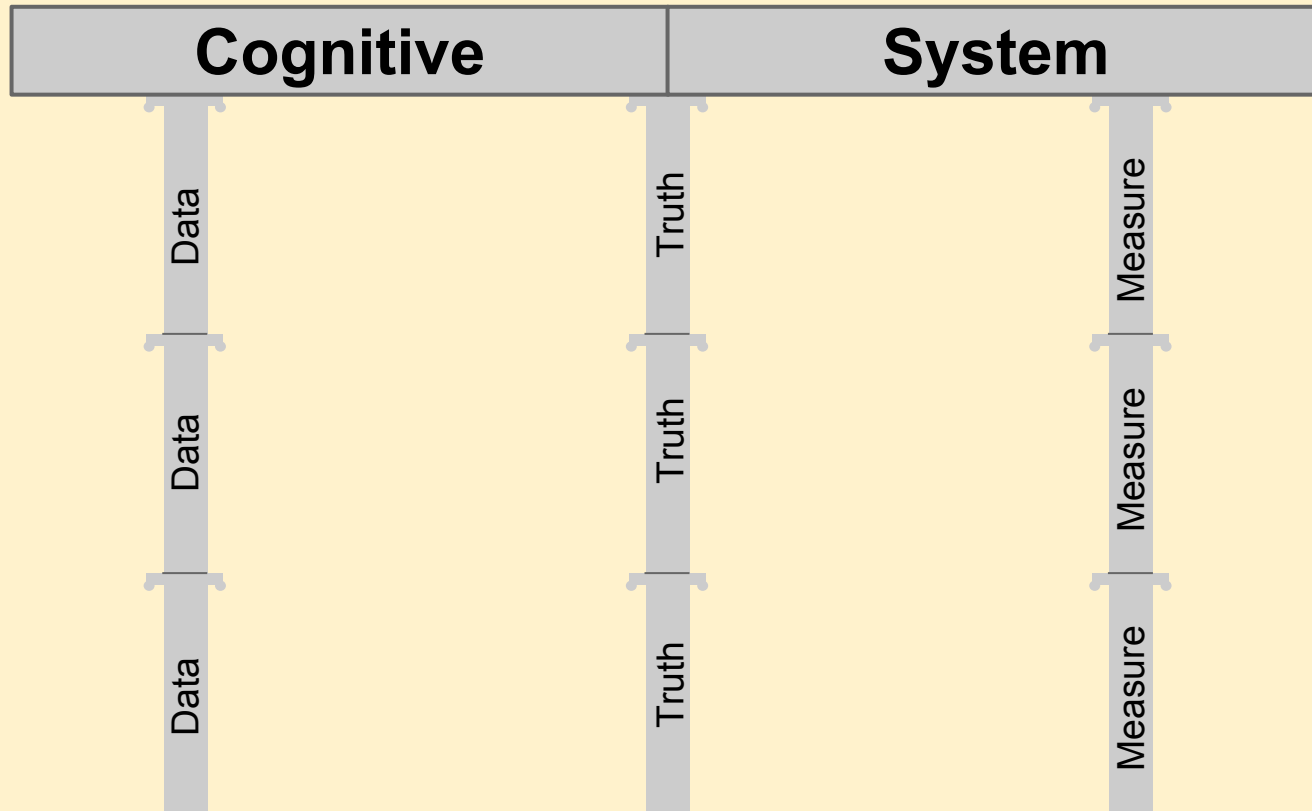
Data, data, data

- Welcome to the data age
- Cognitive system engineers can't have enough
- Customers must be prepared to give up their data

Truth, truth, truth

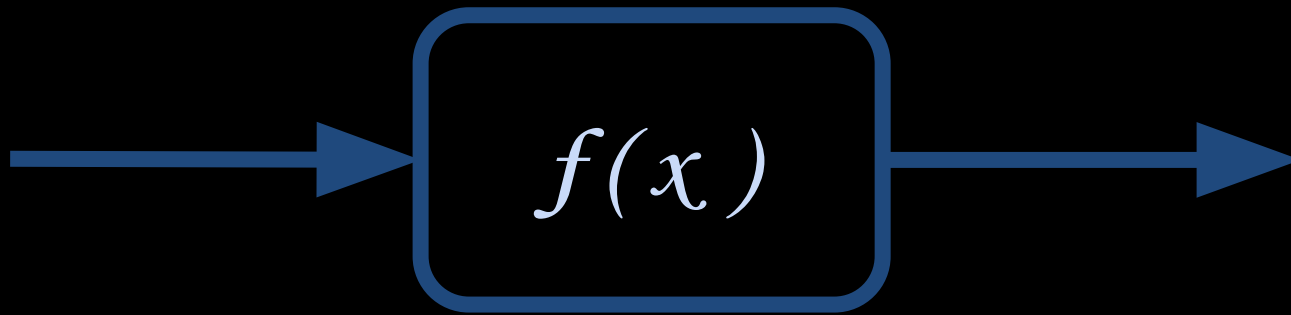
- Data and metrics are not enough
- There has to be a reference standard, often called *ground truth*, to measure against
 - eg QA: questions with the right answer
 - eg search: search queries and correct pages
 - eg parsing: sentences with correct parse trees
- What happens when problems don't have a strict right/wrong outcome? see *CrowdTruth* (w/ Dr. Lora Aroyo & q.v. Todd Carter)
- This is not about supervised learning, this is about measurement & evaluation

The 9 pillars of cognitive systems engineering



The 9 pillars define the cognitive system. If you change one of them, the system should change

Cognitive Computing Distilled



where f is:

machine translation $f(\text{"hello"}) \rightarrow \text{"kalimera"}$

question answering

$f(\text{"what is the capital of Greece"}) \rightarrow \text{"Athens"}$

speech understanding $f(\text{"...noise..."}) \rightarrow \text{"Hello there"}$

Cognitive Digital Assistants

next generation PDA

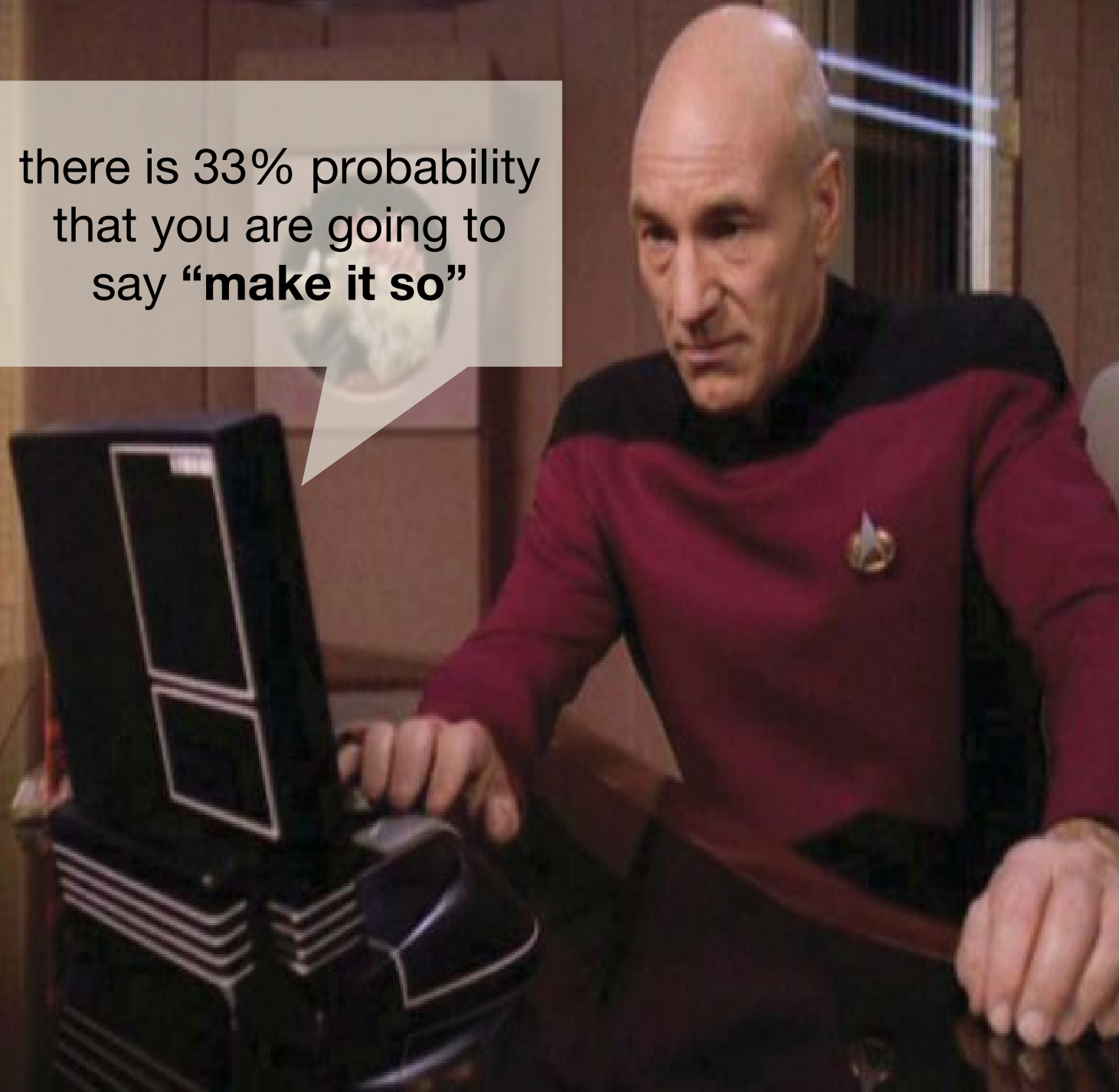
machines modeling
human decision making



your **tea**, **Earl Grey**, hot,
is ready at the replicator



there is 33% probability
that you are going to
say **“make it so”**



Machines behaving badly

via Beethovenstraat 15 min
Mostly flat · [Show bike paths](#) 3.6 km

[Details](#)

via De Boelelaan 16 min

via s110 20 min

via Kanaaldijk West 2 h 9 min
Mostly flat · [Show bike paths](#) 42.0 km

⚠ This route has restricted usage or private roads.

[Details](#)

via Kanaaldijk West and Westkanaaldijk 2 h 15 min

via Kanaaldijk West, Westkanaaldijk and 2 h 18 min

2 h 9 min
42.0 km

I BIKE every day to work

I have a meeting in Utrecht

Would I use the bike to go there?

Machines behaving badly

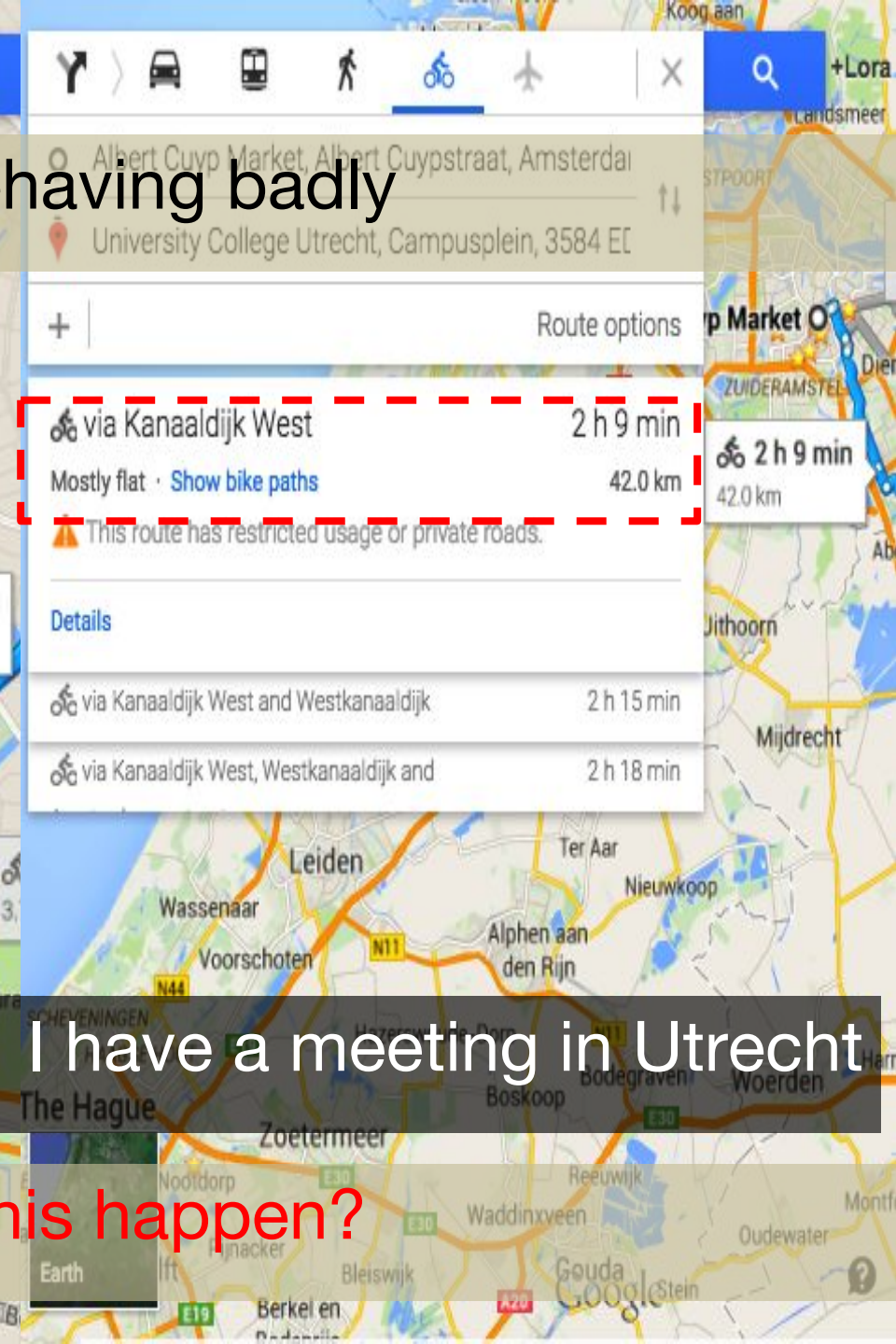
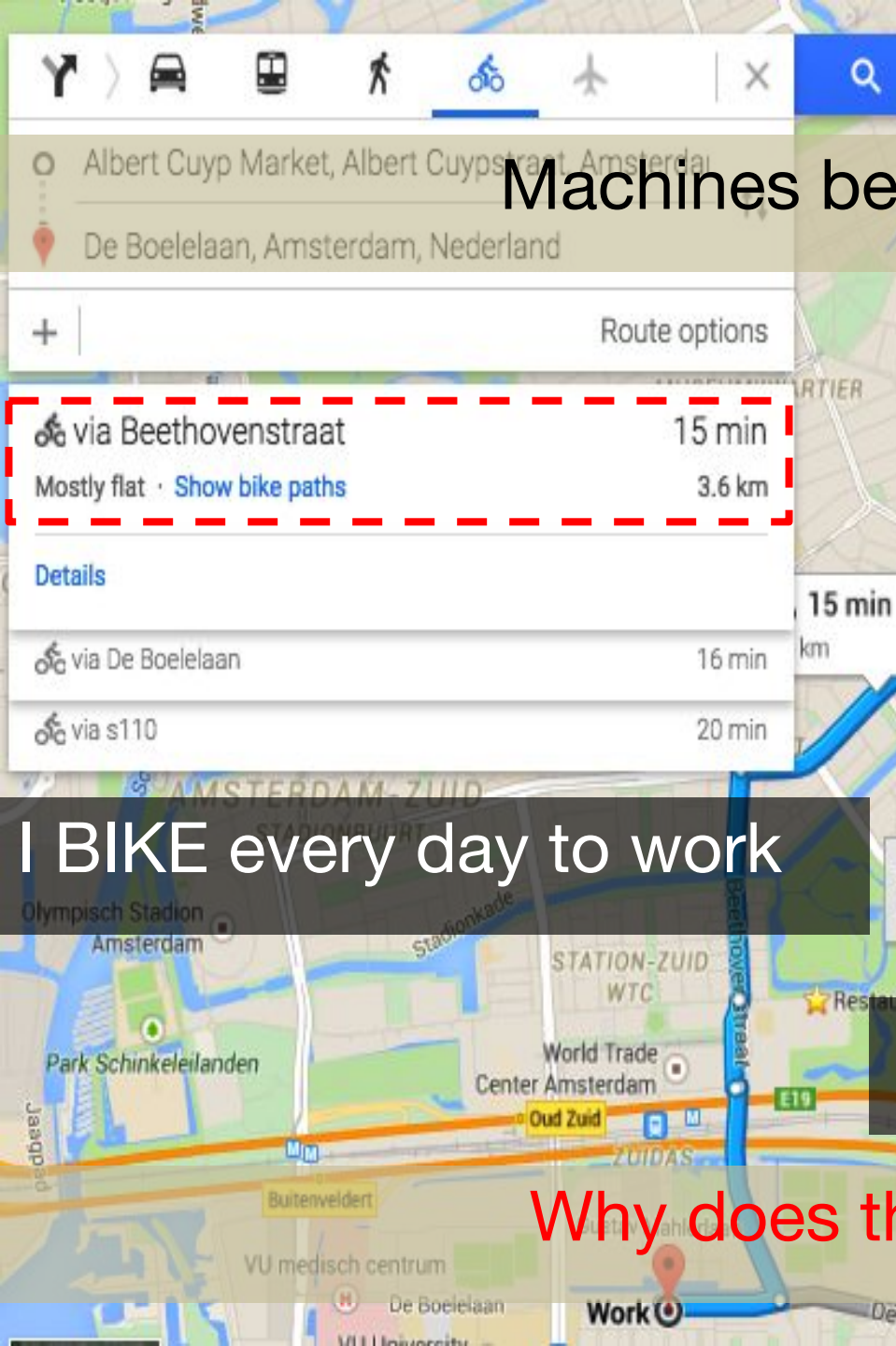
SENSE

I BIKE every day to work

I have a meeting in Utrecht

Would I use the bike to go there?

Machines behaving badly

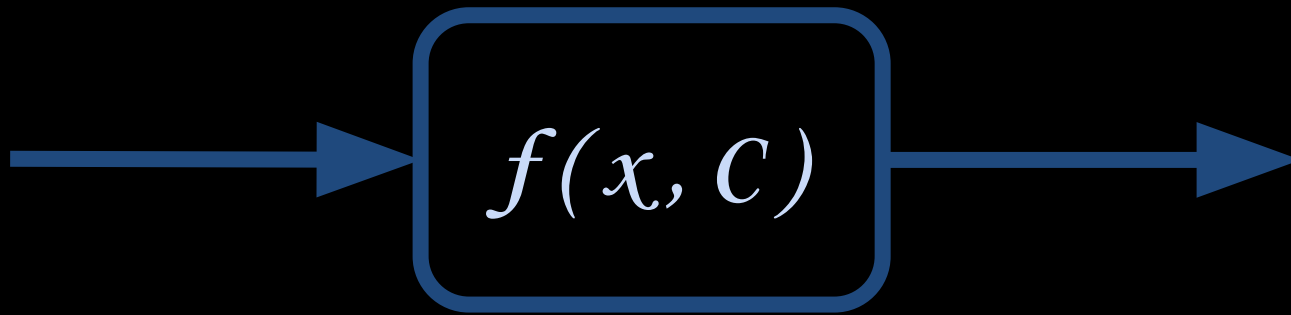


I BIKE every day to work

I have a meeting in Utrecht

Why does this happen?

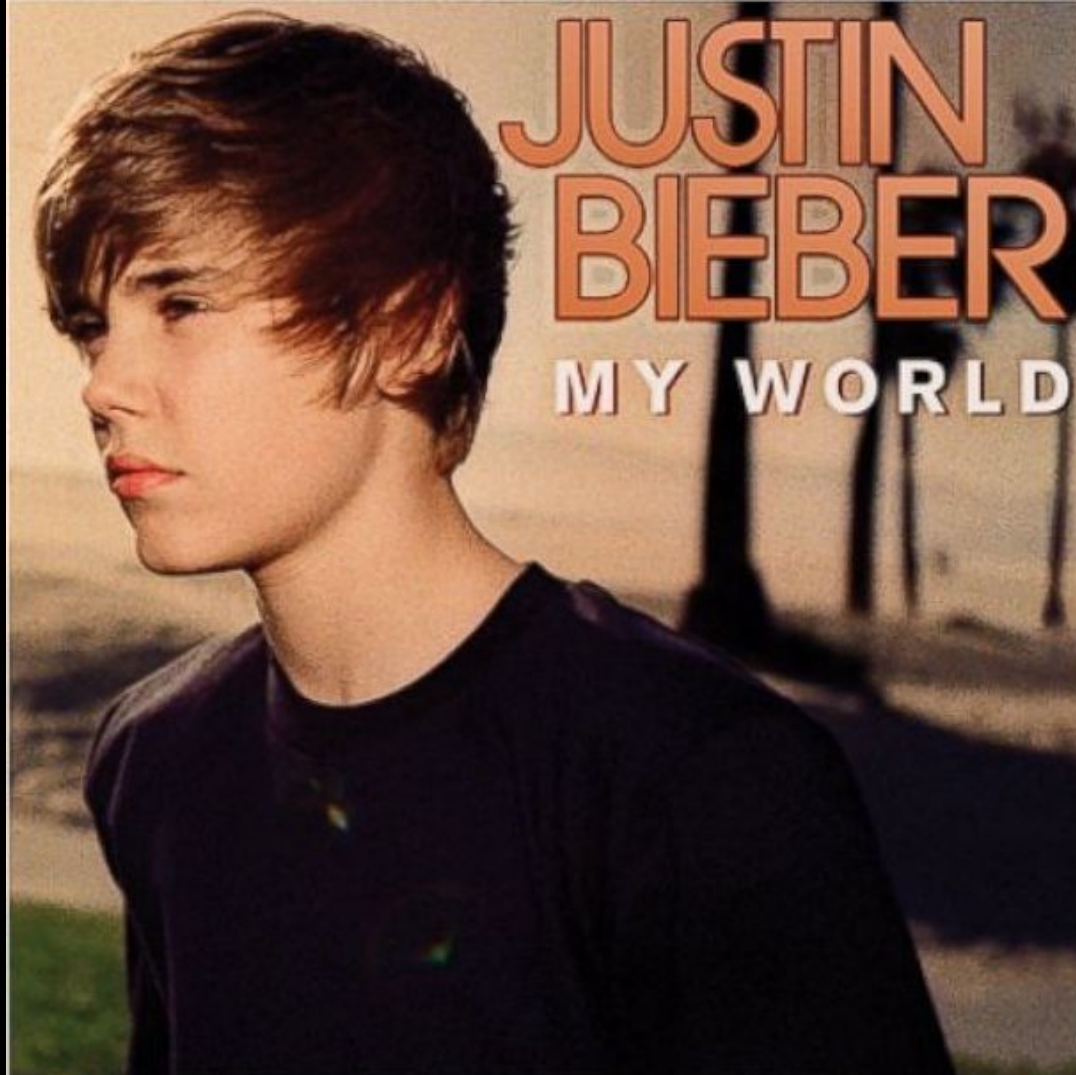
Cognitive Computing Distilled, v2



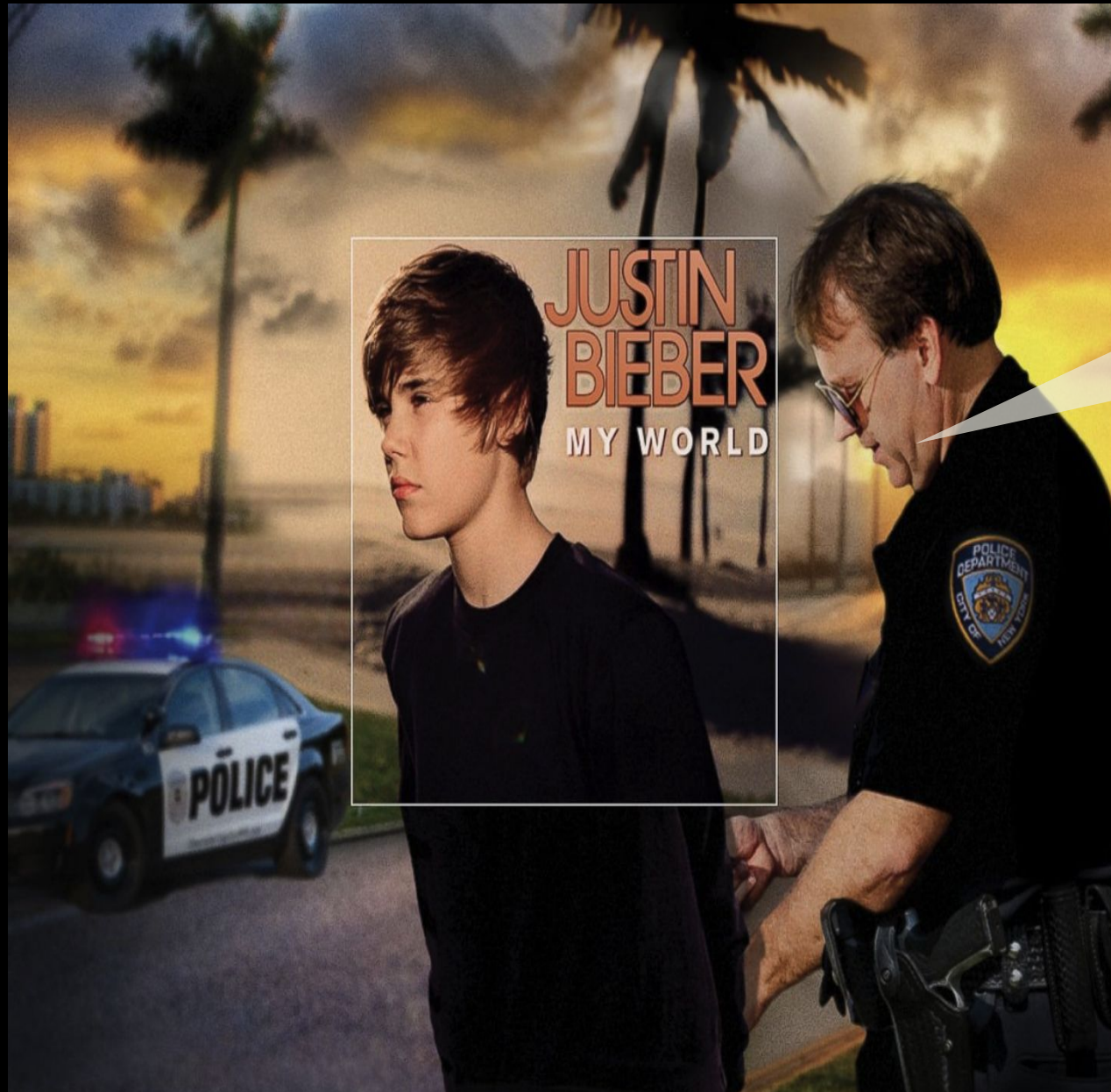
where x is the *primary* sensory input, and C is information about the context.

In practice*, f tends to be a mapping that minimizes some distance measure (metric) between function outputs and known outputs (ground truth)

**whether using machine learning or not*



all the information machines have
is all the information there is



maybe you
should have
biked to work

there is always other kinds of information ...

observations in psychology ...



Order I

76% Gore OK?
58% Clinton OK?

Order II

Clinton OK? 53%
Gore OK? 66%

“irrational human behavior”: order matters



Order I

Clinton OK? 50%
Gore OK? 60%



Order II

68% Gore OK?
57% Clinton OK?

“irrational human behavior”: **order matters**



**foreign
policy**



environment



KEEP
CALM
AND
LIKE
CLINTON

&



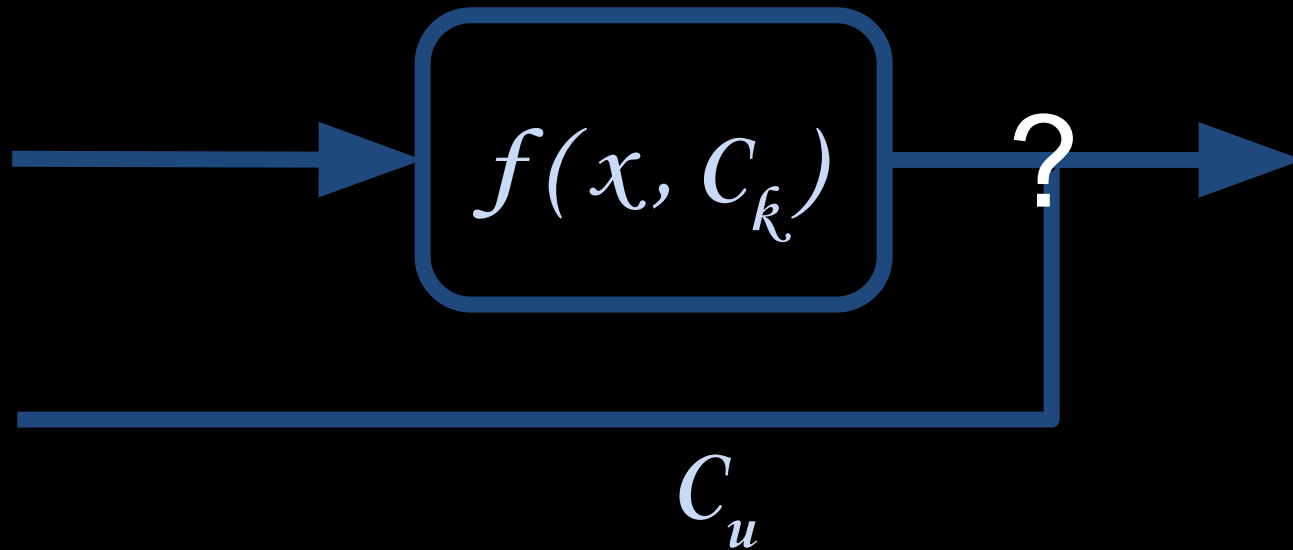
KEEP
CALM
AND
DISLIKE
CLINTON

people **can't** believe **contradictions**



there is always **other** kinds of information ...

Cognitive Computing Distilled, v3



where x is the *primary* sensory input, and C is information about the context, C_k is the known context, C_u is unknown context.

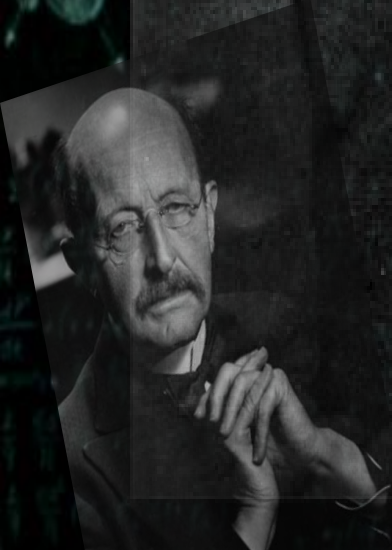
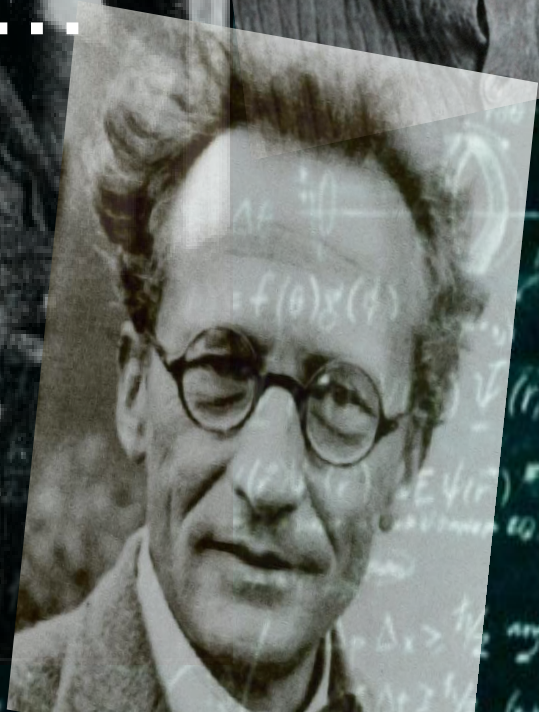
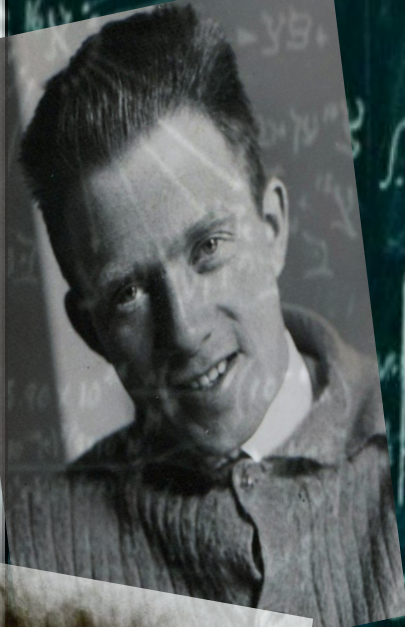
**whether using machine learning or not*

back in the day...

A collage of historical figures and a chalkboard with mathematical formulas. The central figure is a man in a suit, looking to the right. Behind him, another man with a mustache is visible. In the bottom left corner, there is a small portrait of a man with glasses and a mustache. In the bottom right corner, there is a small portrait of a man with glasses. The background is a chalkboard filled with various mathematical formulas and diagrams. Overlaid on the image is the text "back in the day..." in a white, sans-serif font. Below this text, the word "SENSE" is written in a large, bold, white, sans-serif font, and it is crossed out with a thick red circle and a diagonal slash.



SENSE



single slit

double slit
(expected)





we need new math

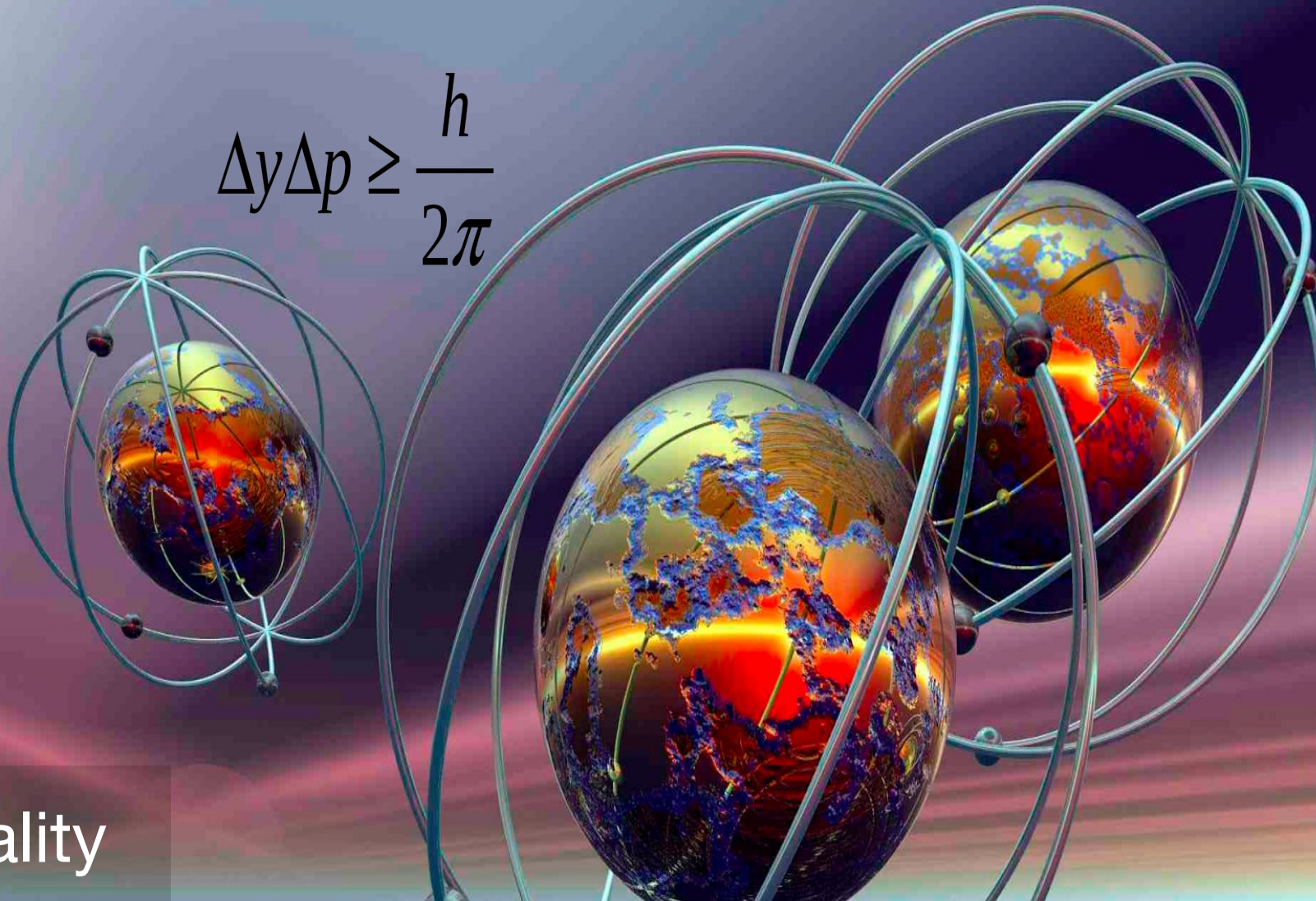


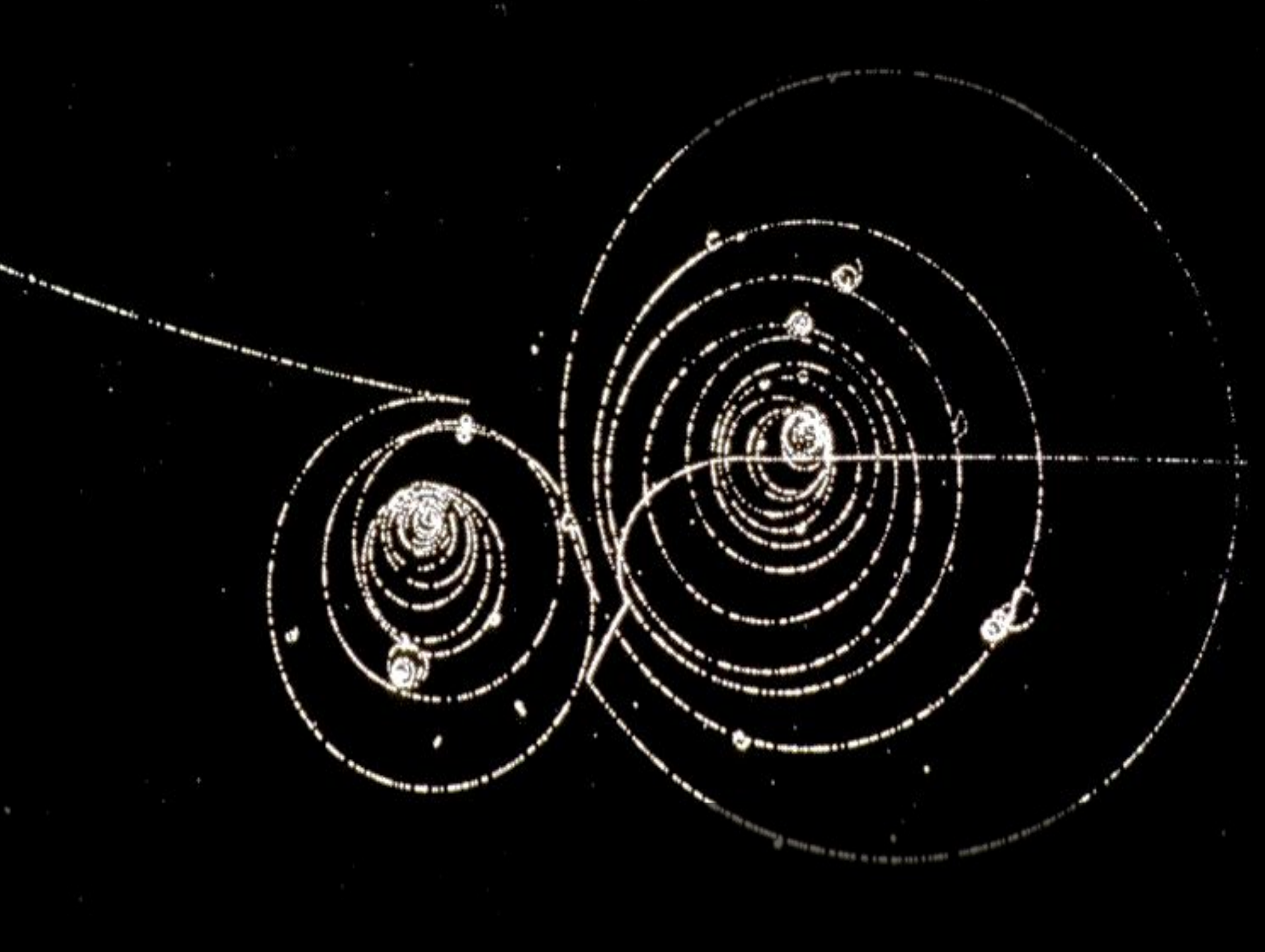
uncertainty

entanglement

$$\Delta y \Delta p \geq \frac{h}{2\pi}$$

duality







KEEP
CALM
AND
LIKE
CLINTON

&

KEEP
CALM
AND
DISLIKE
CLINTON

quantum math makes sense of irrational human behavior

$$P(E) + P(\text{not } E) = 1$$



$$P(\text{like Clinton}) = .58$$



$$P(\text{not like Clinton}) = 1 - .58 = .42$$



**foreign
policy**

Gore

Bush

**Monica
Lewinsky**

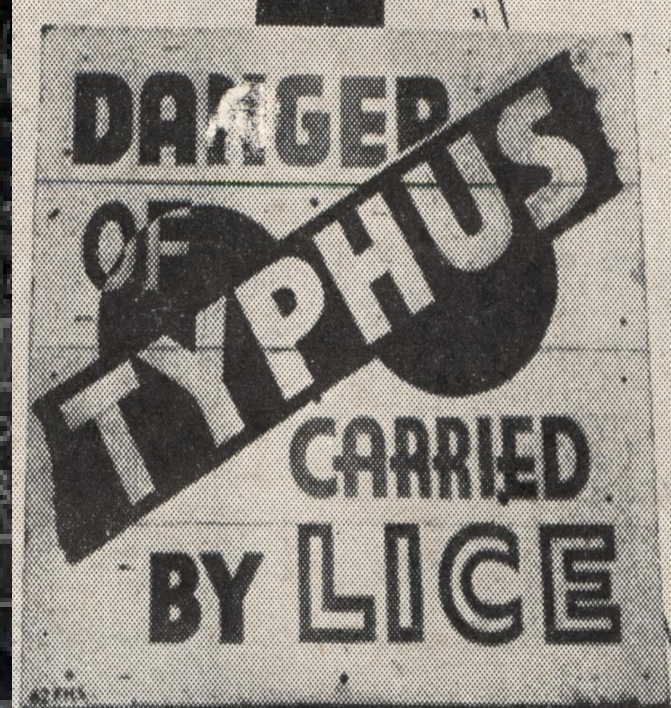
**my feet
hurt**

Medical Crowd Truth

Antibiotics treat Typhus?



$$P(\text{smiley}) = .75$$



Antibiotics doesn't treat Typhus?



$$P(\text{sad}) = .50$$

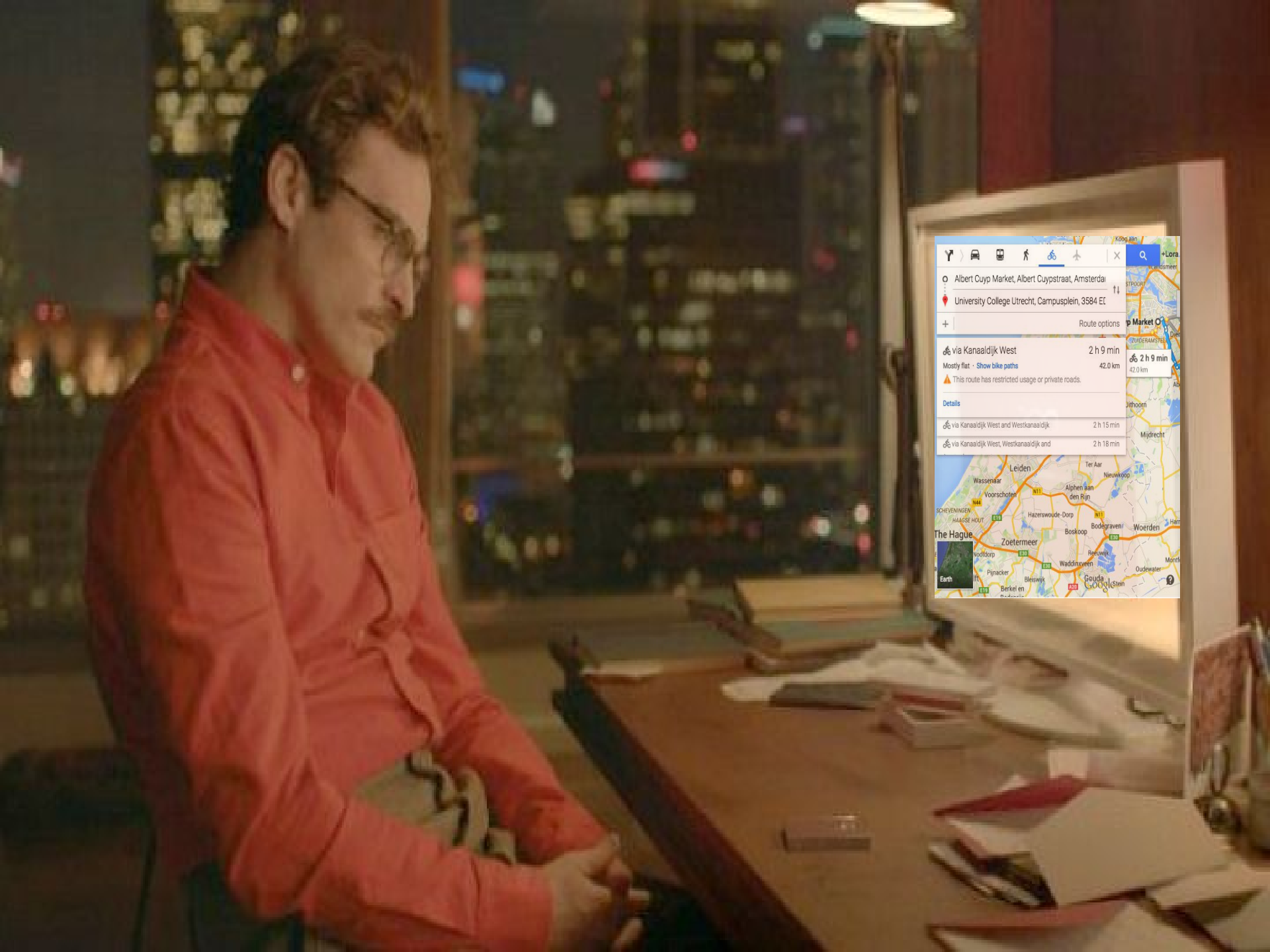
$$P(\text{😊}) = .75$$
$$P(\text{😞}) = .50$$

$$.75 + .50 \neq 1$$

Quantum Theory:
Context effect .25

Probability Theory:

SENSE



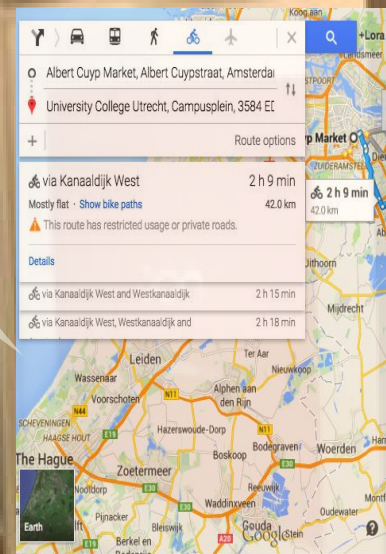
Navigation interface showing route options between Albert Cuyp Market, Amsterdam and University College Utrecht, Utrecht.

Route options:

- via Kanaaldijk West** 2 h 9 min
Mostly flat - [Show bike paths](#) 42.0 km
⚠️ This route has restricted usage or private roads.
- via Kanaaldijk West and Westkanaaldijk** 2 h 15 min
- via Kanaaldijk West, Westkanaaldijk and** 2 h 18 min

Map view showing the region around Leiden, The Hague, and Zoetermeer.

you seem
moody today,
shall I just call
you a cab?

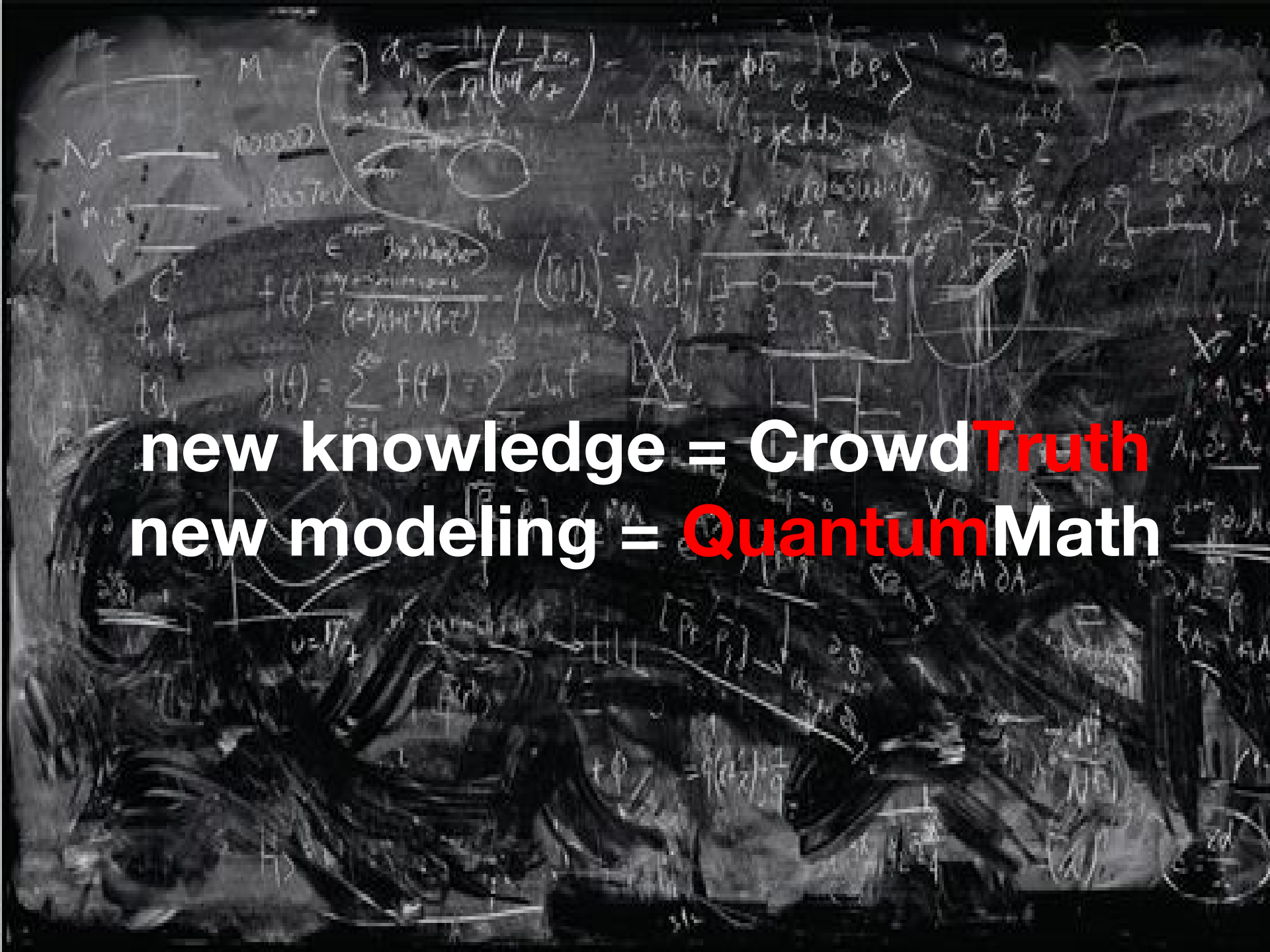




the world is changed

machine learning

facing a fundamental shift



new knowledge = CrowdTruth
new modeling = QuantumMath



Quantum Truth
makes sense

Cognitive
systems can be
wrong and be
useful!

፲ ሙሉ ምዕራብ ሕዝብ

I amar prestar aen
The world has changed

