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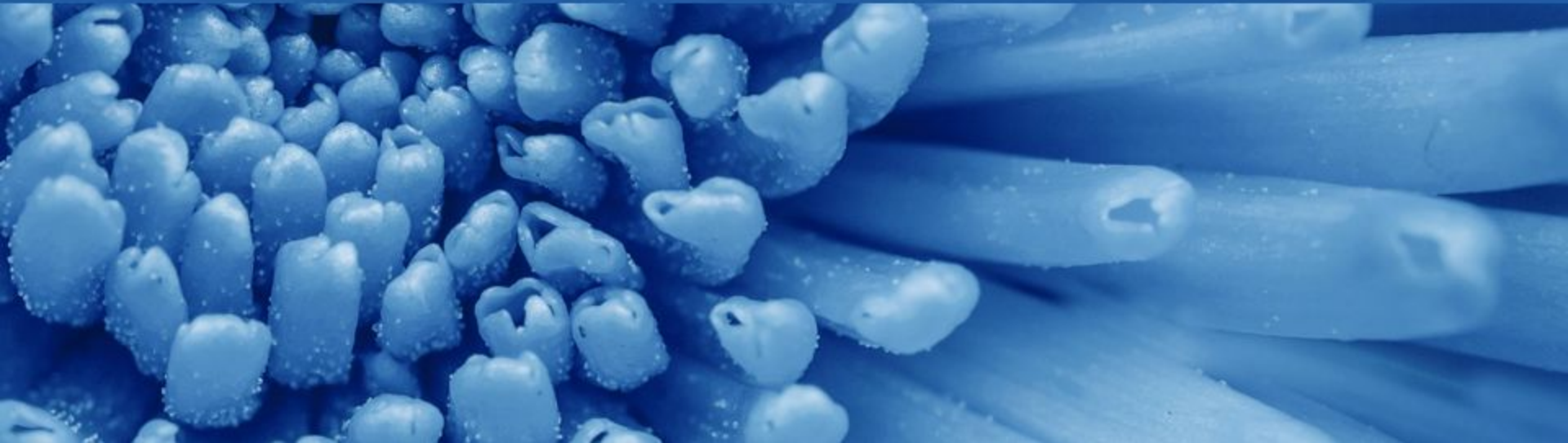
Karlsruher Institut für Technologie

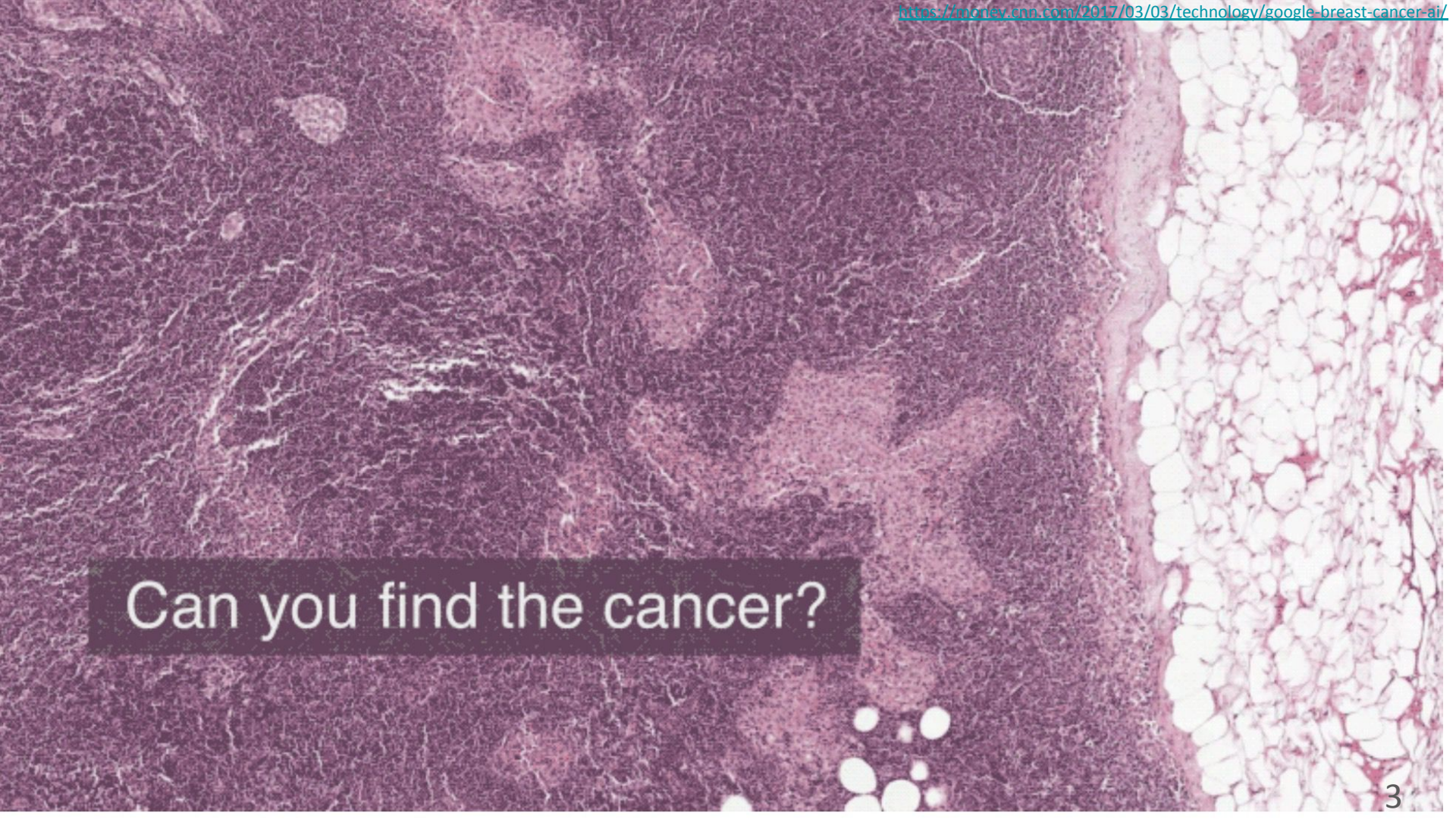
Artificial Intelligence for Cultural Heritage

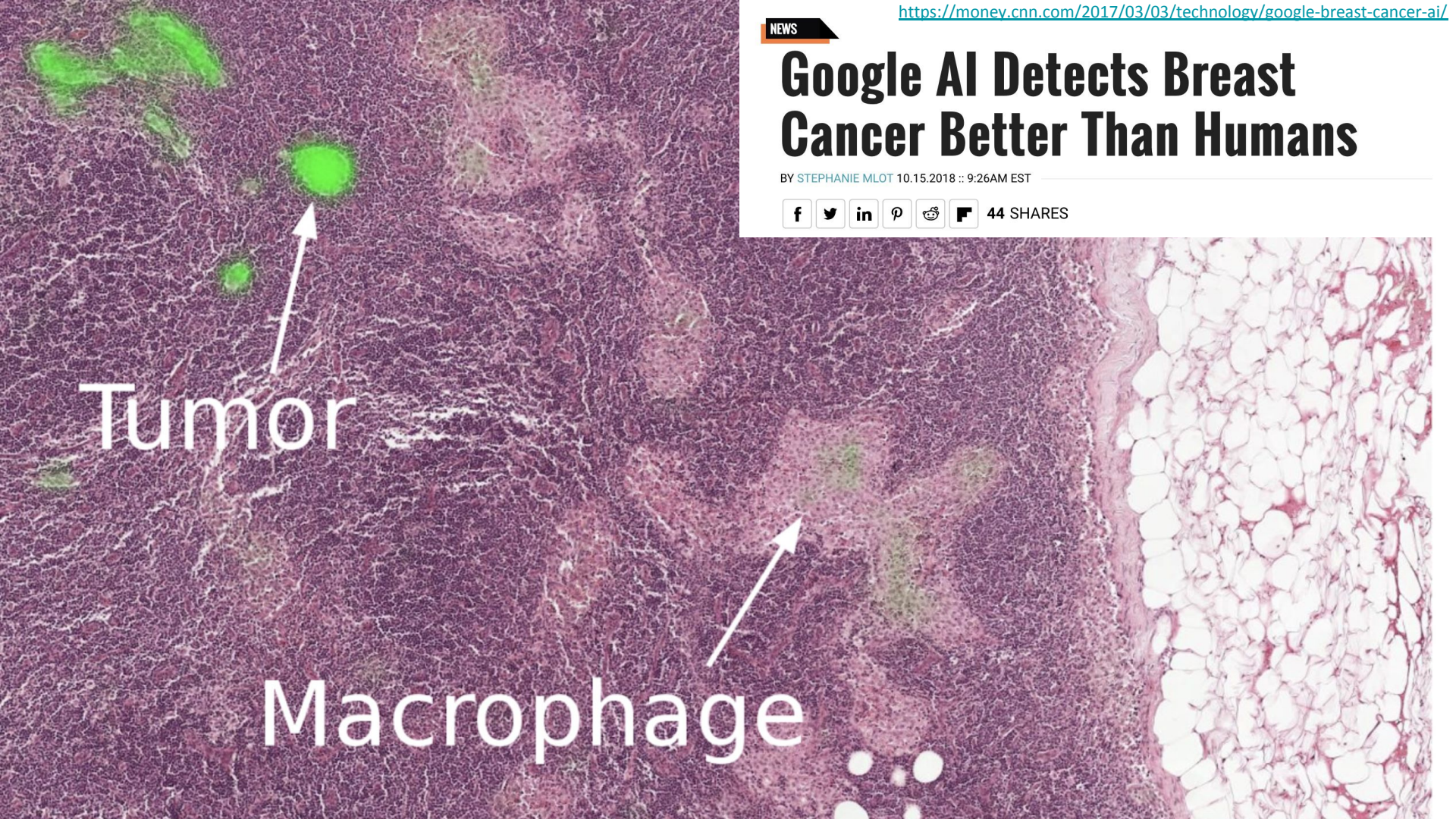
Prof. Dr. Harald Sack
Europeana 2019
Lisbon, November 27, 2019

“Any sufficiently advanced technology is indistinguishable from magic.”

Arthur C. Clarke, Profiles of the Future (1973)




https://money.cnn.com/2017/03/03/technology/google-breast-cancer-ai/
Can you find the cancer?



https://money.cnn.com/2017/03/03/technology/google-breast-cancer-ai/

NEWS

Google AI Detects Breast Cancer Better Than Humans

BY STEPHANIE MLOT 10.15.2018 :: 9:26AM EST

44 SHARES

Science

AlphaGo Zero: Google DeepMind supercomputer learns 3,000 years of human knowledge in 40 days

AlphaGo

http://www.telegraph.co.uk/science/2017/10/18/alphago-zero-google-deepmind-supercomputer-learns-3000-years/

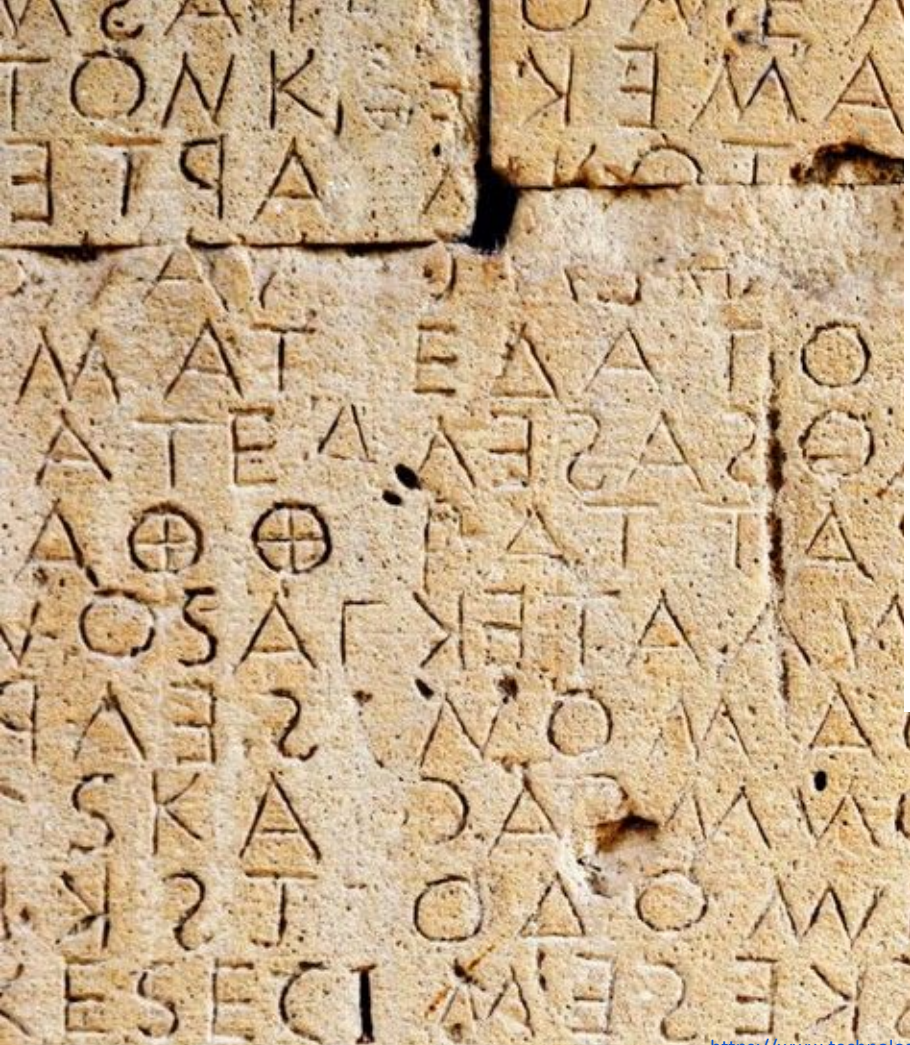
https://www.christies.com/features/A-collaboration-between-two-artists-one-human-one-a-machine-9332-1.aspx

Is artificial intelligence set to become art's next medium?

16 October 2018

PHOTOGRAPHS & PRINTS |

AI artwork sells for $432,500 — nearly 45 times its high estimate — as Christie's becomes the first auction house to offer



Humans and Technology

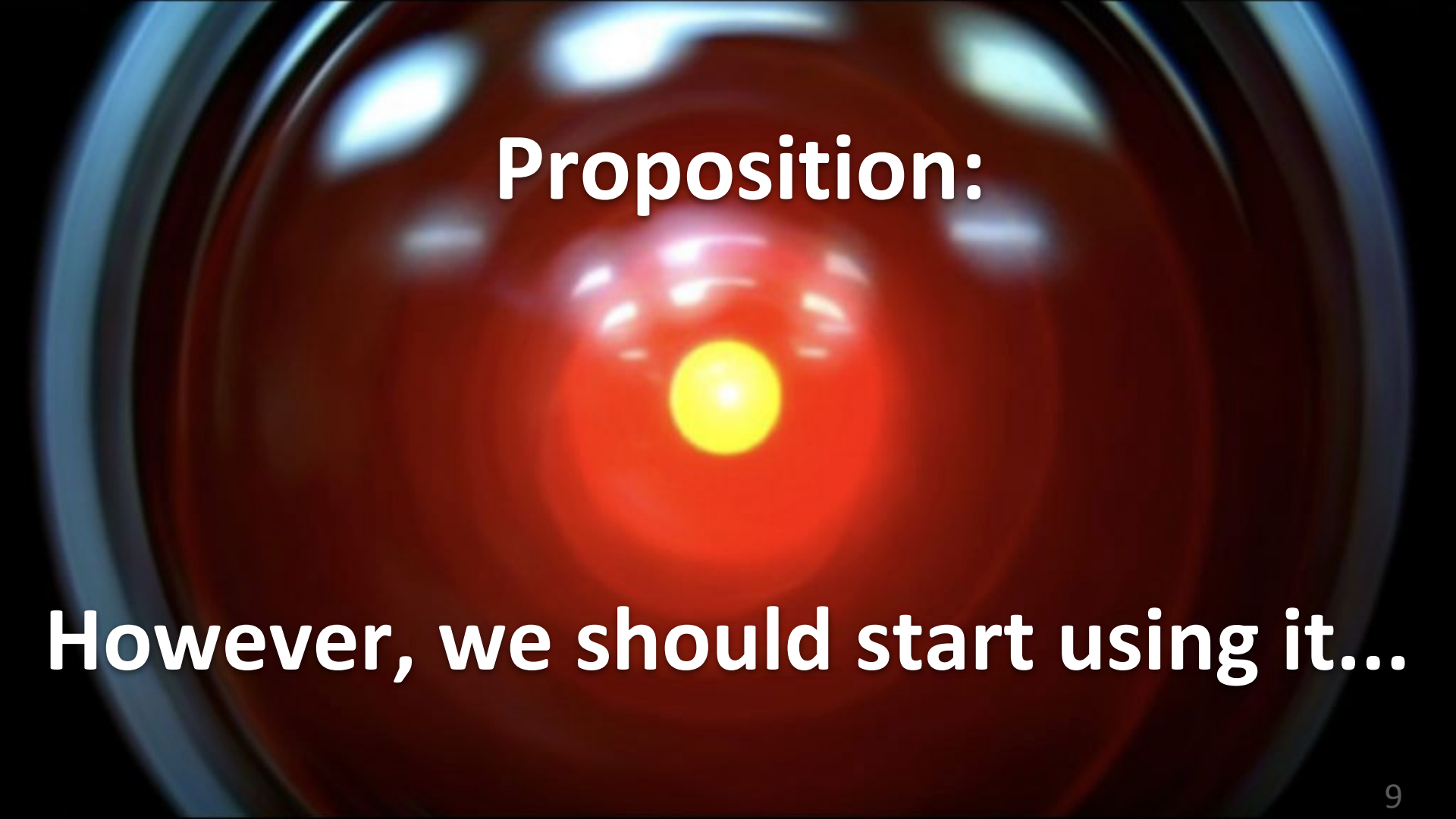
Machine learning has been used to automatically translate long-lost languages

Some languages that have never been deciphered could be the next ones to get the machine translation treatment.

by **Emerging Technology from the arXiv** Jul 1, 2019

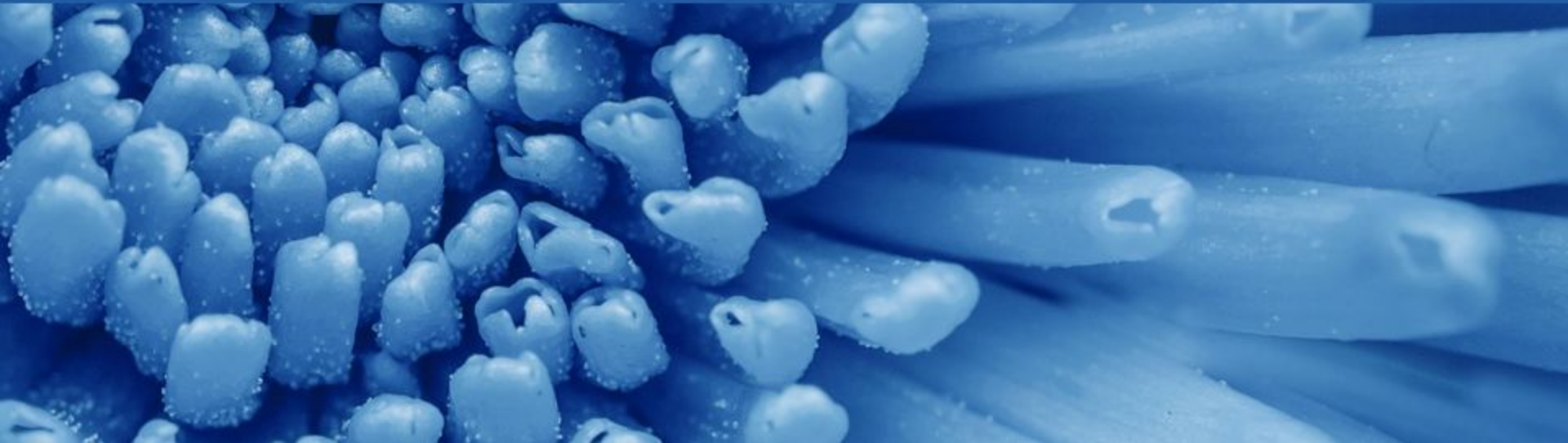
https://www.technologyreview.com/s/613899/machine-learning-has-been-used-to-automatically-translate-long-lost-languages/


"...in from three to eight years we will have a machine with the general intelligence of an average human being", Marvin Minsky (1970)
Are we all doomed…?
...or do we simply have a tendency to overestimate technology?

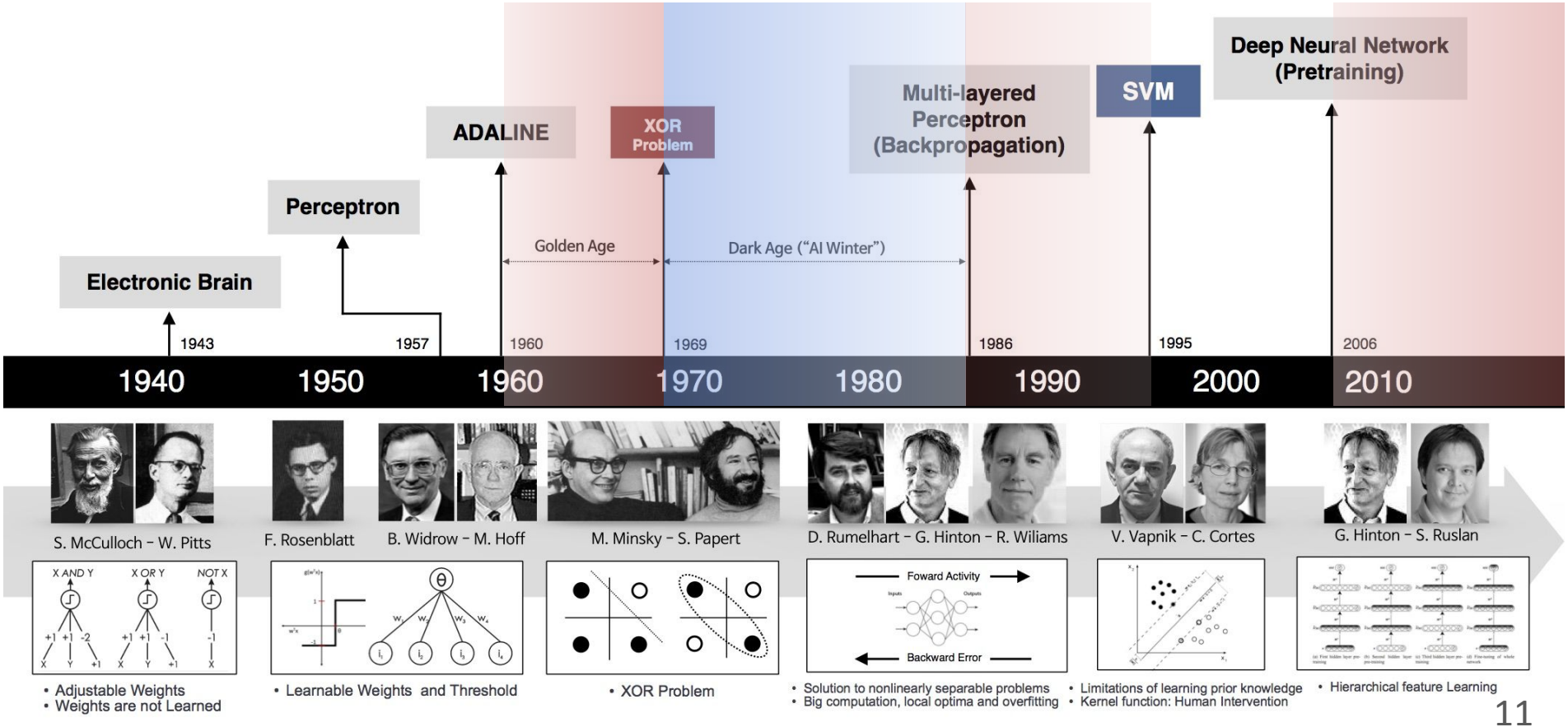

Proposition:
However, we should start using it...

“Nothing succeeds like success.”

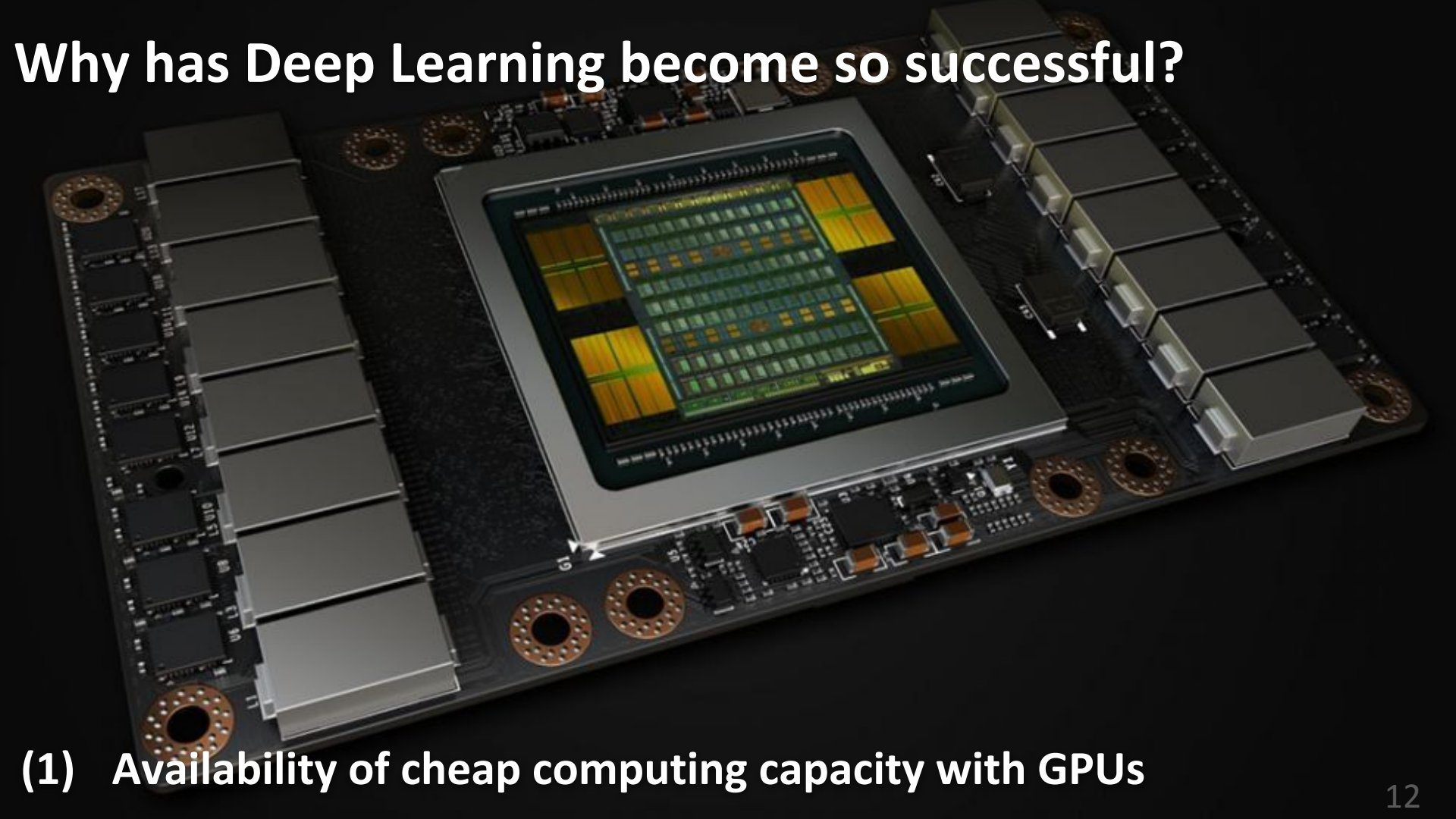
Alexandre Dumas, *Ange Pitou*, Vol.I (1854)



The Triumph of the Connectionist Paradigm



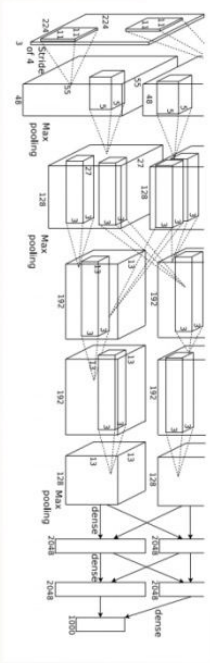
Why has Deep Learning become so successful?



(1) Availability of cheap computing capacity with GPUs

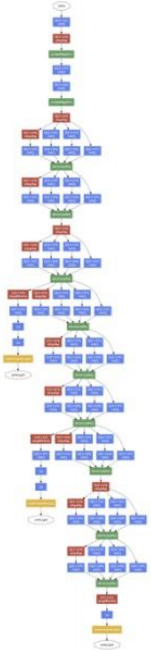
(2) Reusable Highly Trained Complex Models

“AlexNet”



[Krizhevsky et al. NIPS 2012]

“GoogLeNet”

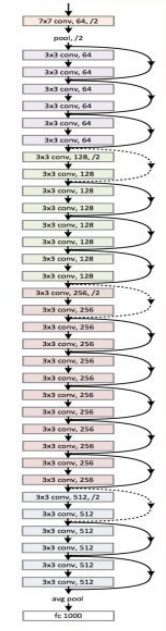


[Szegedy et al. CVPR 2015]

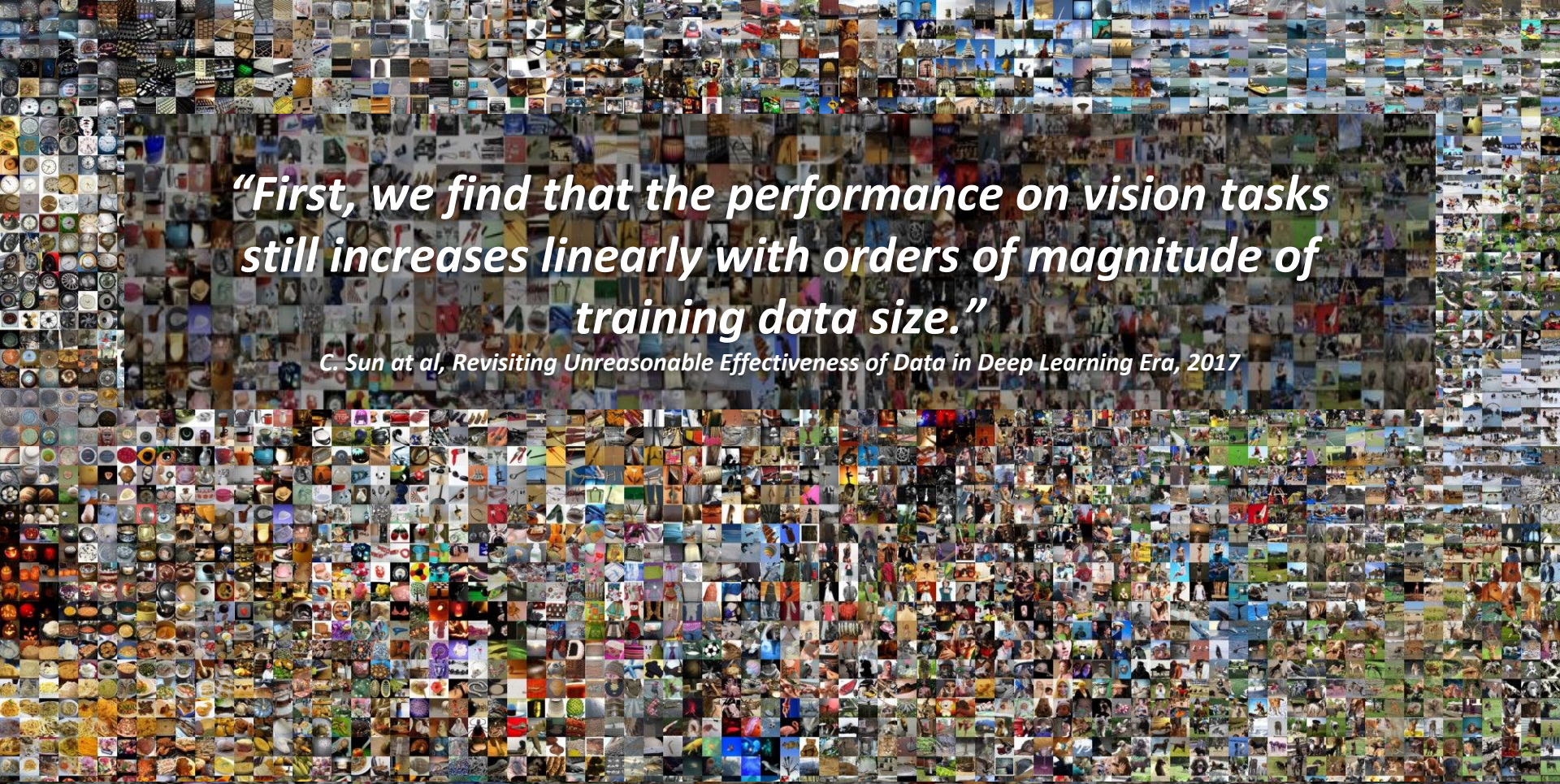
“VGG Net”

[Simonyan & Zisserman, ICLR 2015]

“ResNet”



[He et al. CVPR 2016]

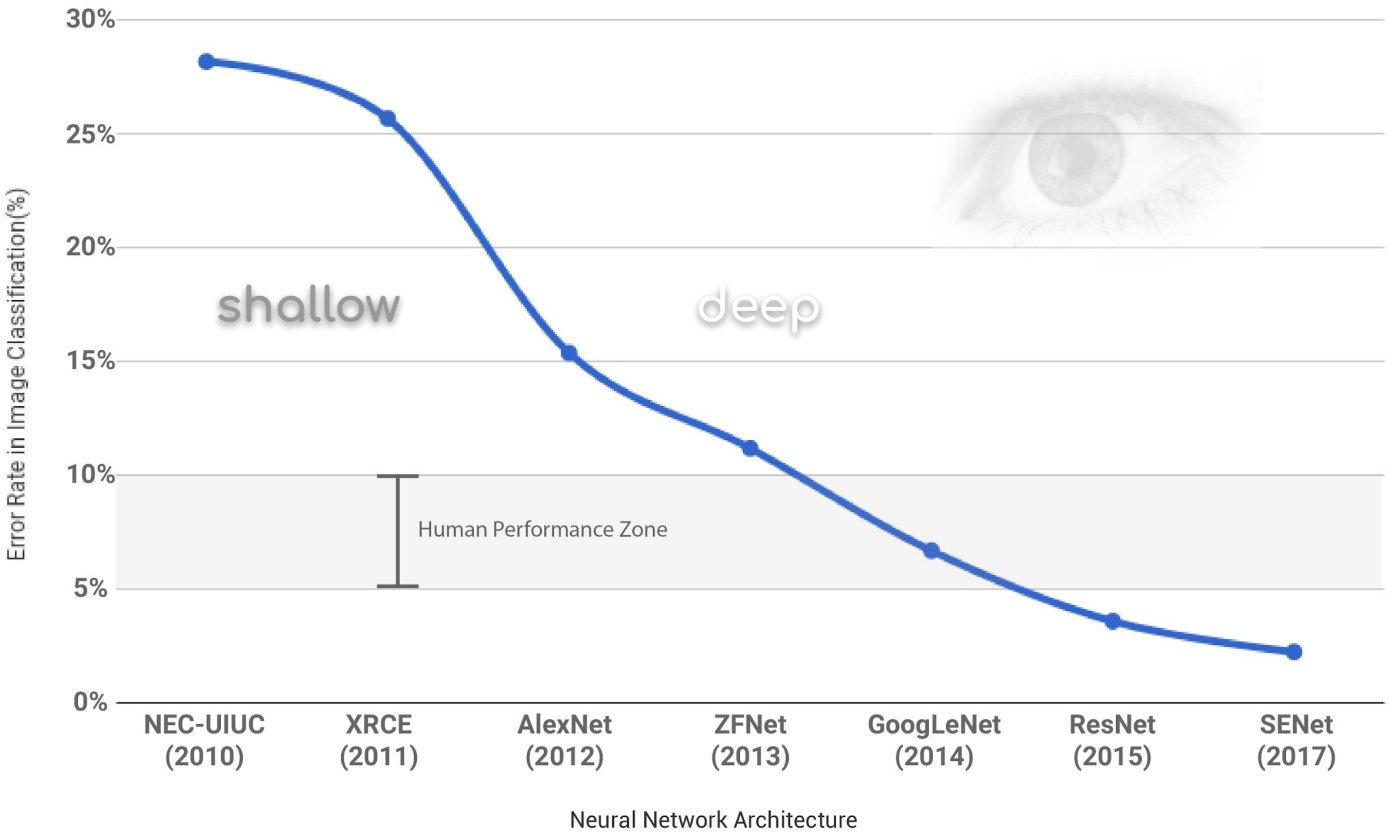


"First, we find that the performance on vision tasks still increases linearly with orders of magnitude of training data size."

C. Sun at al, Revisiting Unreasonable Effectiveness of Data in Deep Learning Era, 2017

(3) Availability of Large Scale Labeled Data

Deep Learning for Visual Analysis



IMAGENET

Large Scale Visual Recognition Challenge (ILSVRC)

http://image-net.org/challenges/LSVRC/

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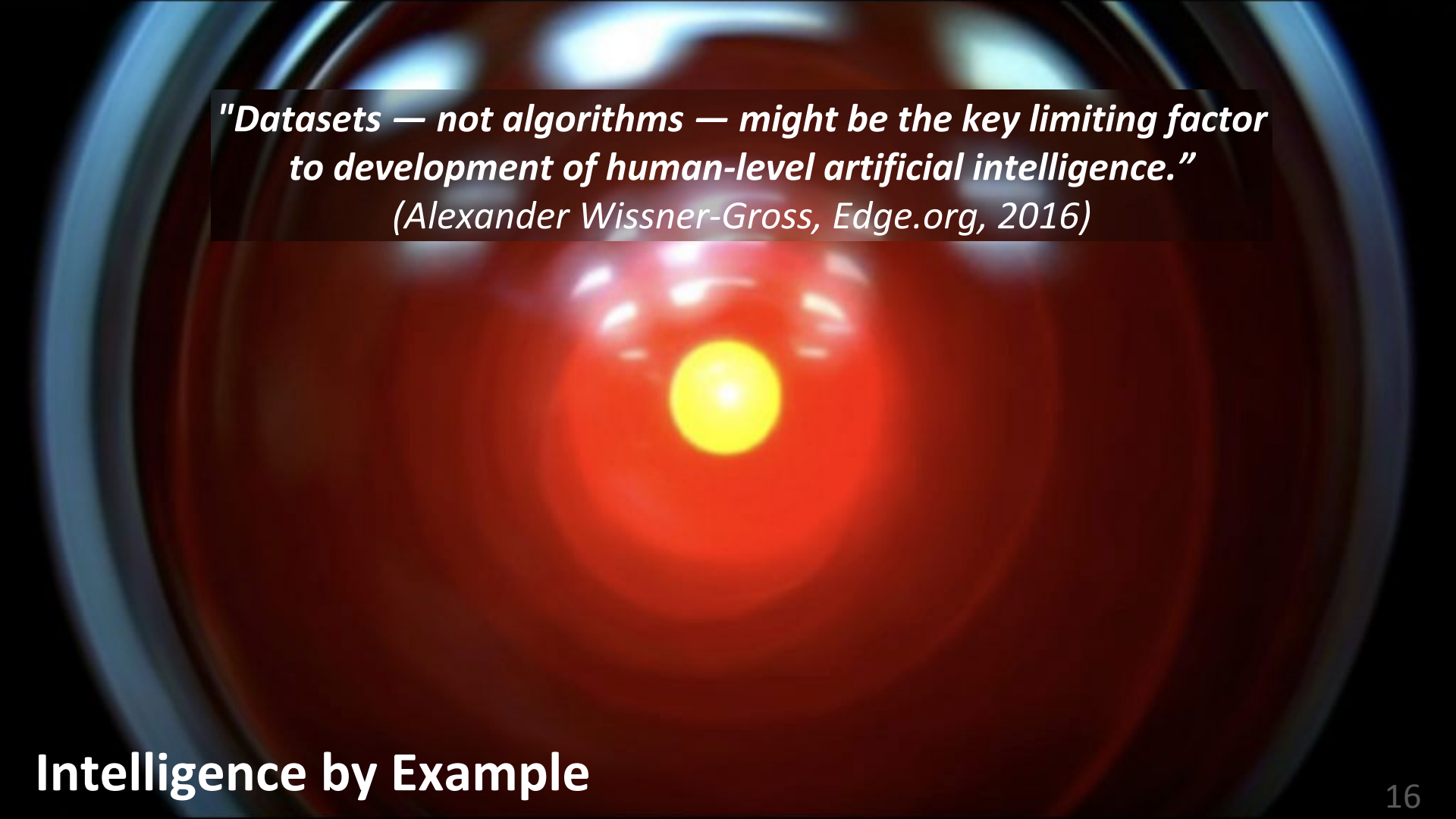
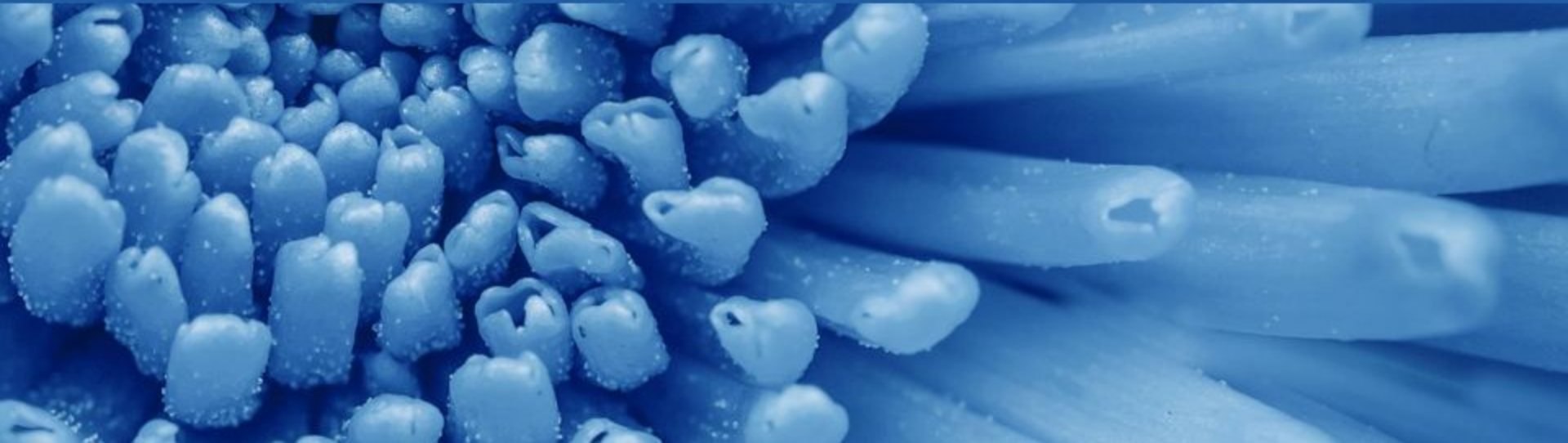


Intelligence by Example

“Creation is never complete.
It started once, but it will never stop.”

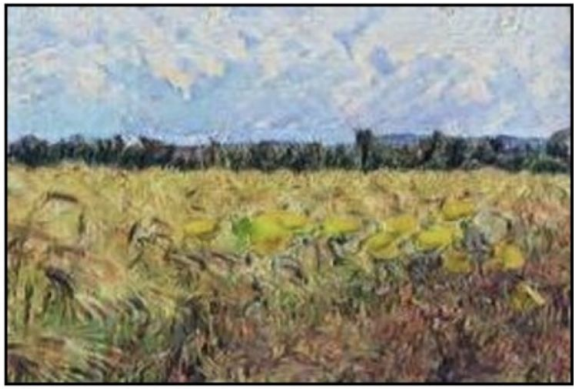
Immanuel Kant, General Natural History and Theory of Heaven (1755)



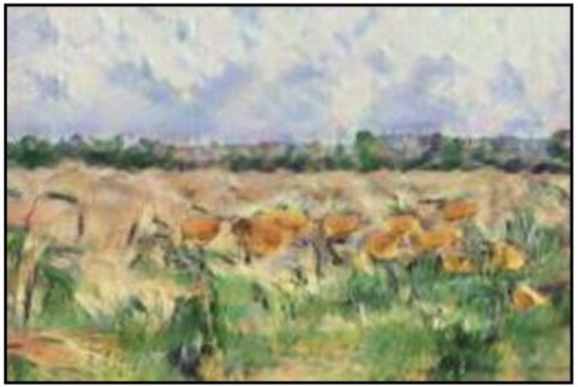
Creation of New Content - Cross Domain Transfer

Photograph

Monet



Van Gogh



Cezanne

Ukiyo-e

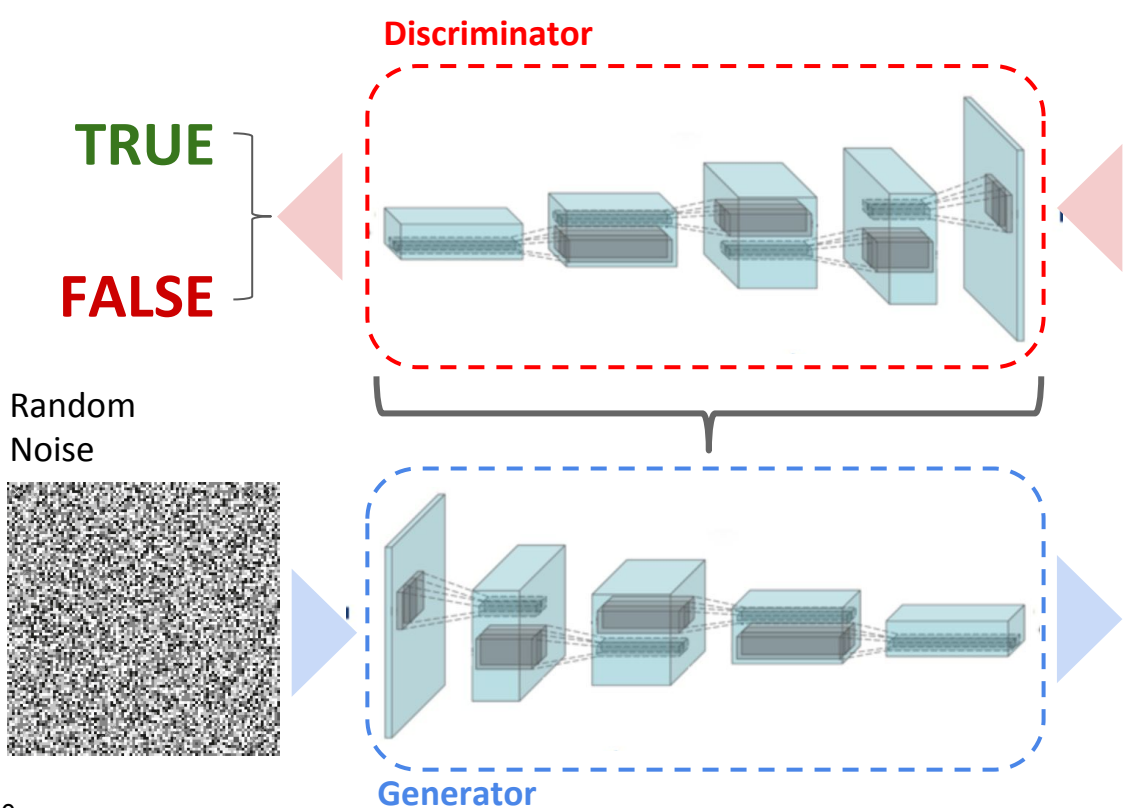
https://junyanz.github.io/CycleGAN/images/teaser_high_res.jpg

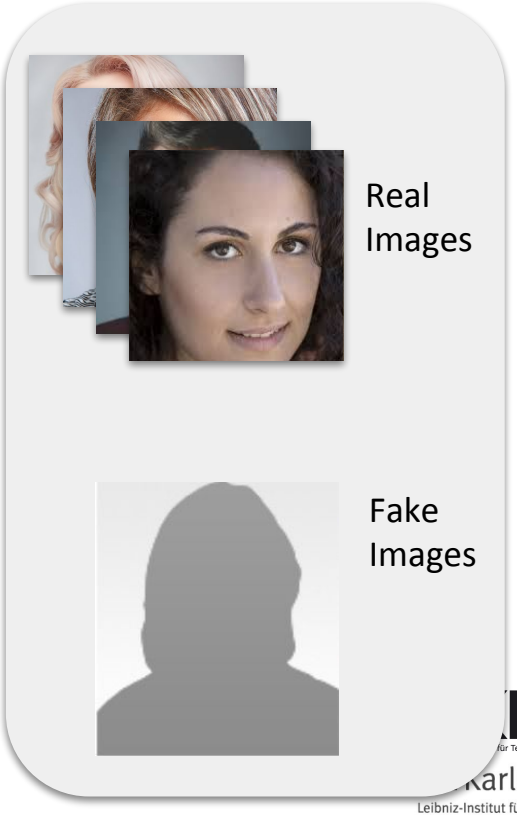
Creation of New Content - Cross Domain Transfer

Monet → Photograph

https://junyanz.github.io/CycleGAN/images/teaser_high_res.jpg

Comparative Learning - Generative Adversarial Networks





Schmidthuber, 1992
Niemitalo, 2010
Goodfellow, 2014

Creation of New Content - Cross Domain Transfer

https://junyanz.github.io/CycleGAN/

https://github.com/jantic/DeOldify

Generation of New Content - Colourization

Generation of New Content - Super Resolution

https://arxiv.org/pdf/1609.04802.pdf

bicubic
(21.59dB/0.6423)

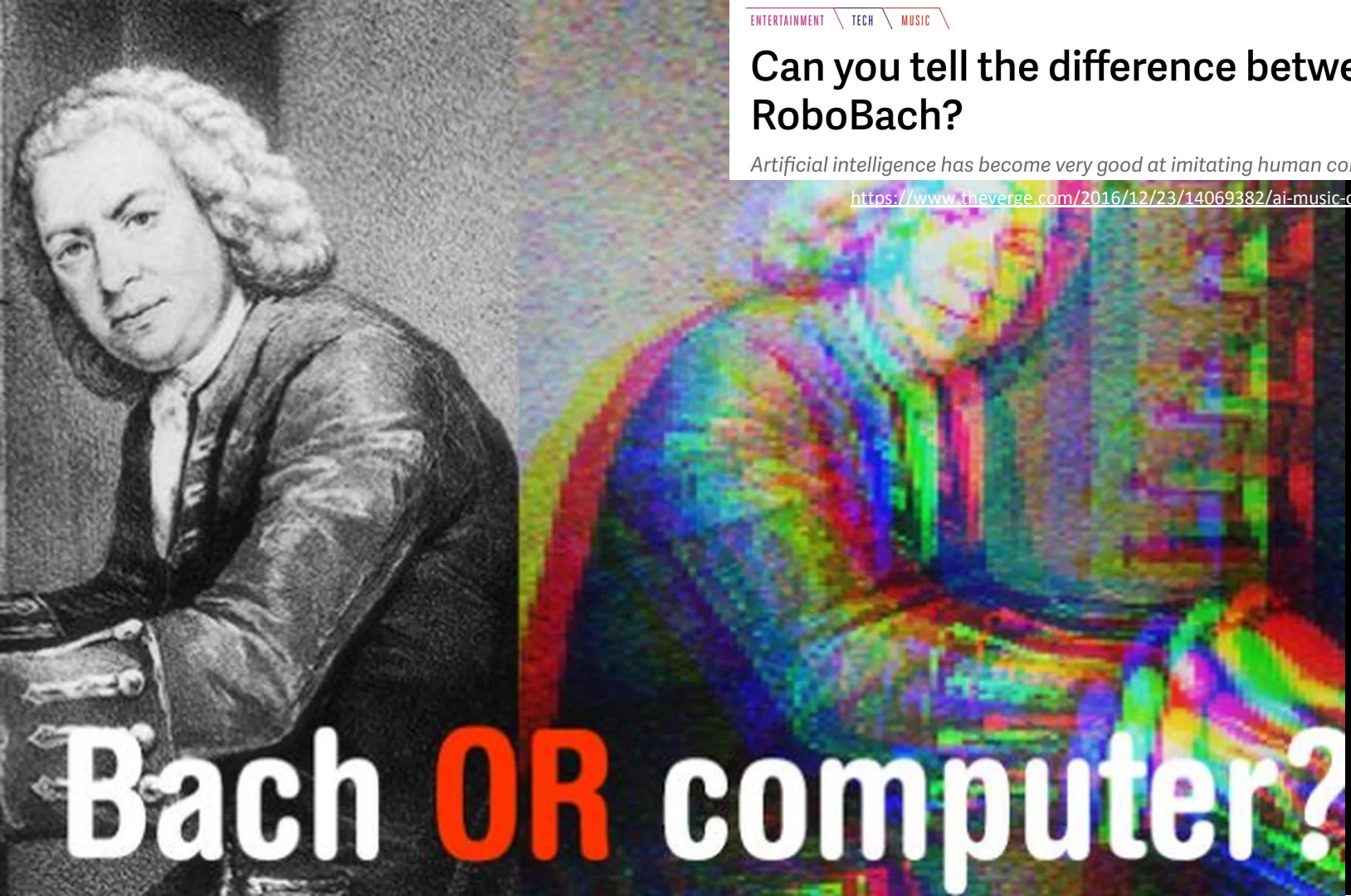
SRResNet
(23.53dB/0.7832)

SRGAN
(21.15dB/0.6868)

original

Generation of New Content - Text to Images

Han Zhang, Tao Xu, Hongsheng Li, Shaoting Zhang, Xiaogang Wang, Xiaolei Huang, Dimitris N. Metaxas:
StackGAN++: Realistic Image Synthesis with Stacked Generative Adversarial Networks.
CoRR abs/1710.10916 (2017)



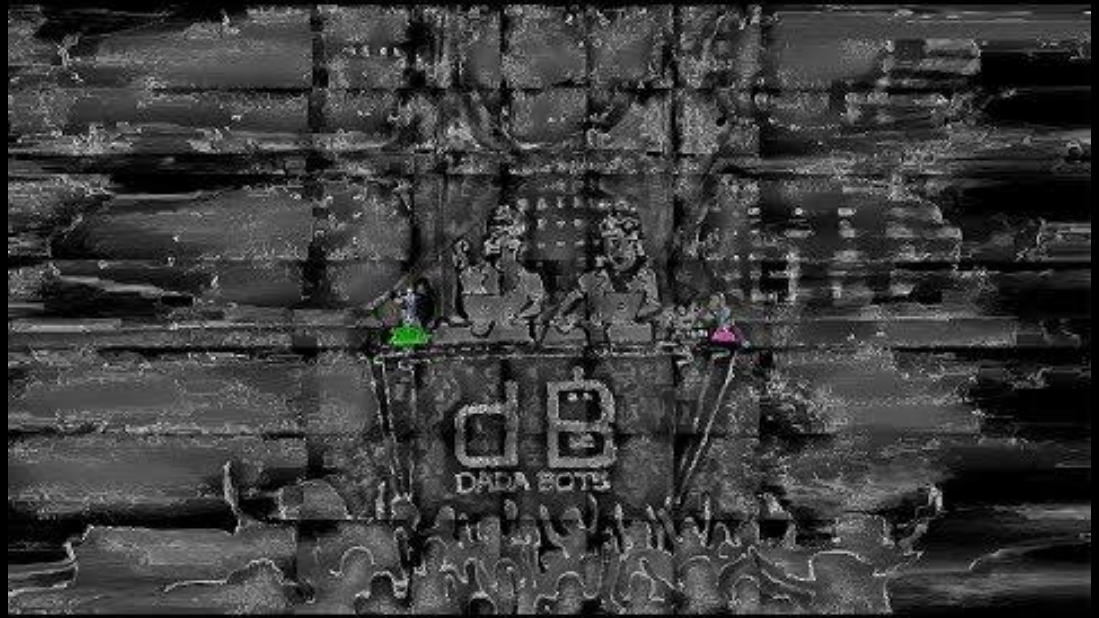
ENTERTAINMENT | TECH | MUSIC

Can you tell the difference between Bach and RoboBach?

Artificial intelligence has become very good at imitating human composers

https://www.theverge.com/2016/12/23/14069382/ai-music-creativity-bach-deepbach-csl

https://www.youtube.com/watch?v=CNNmBtNcccE

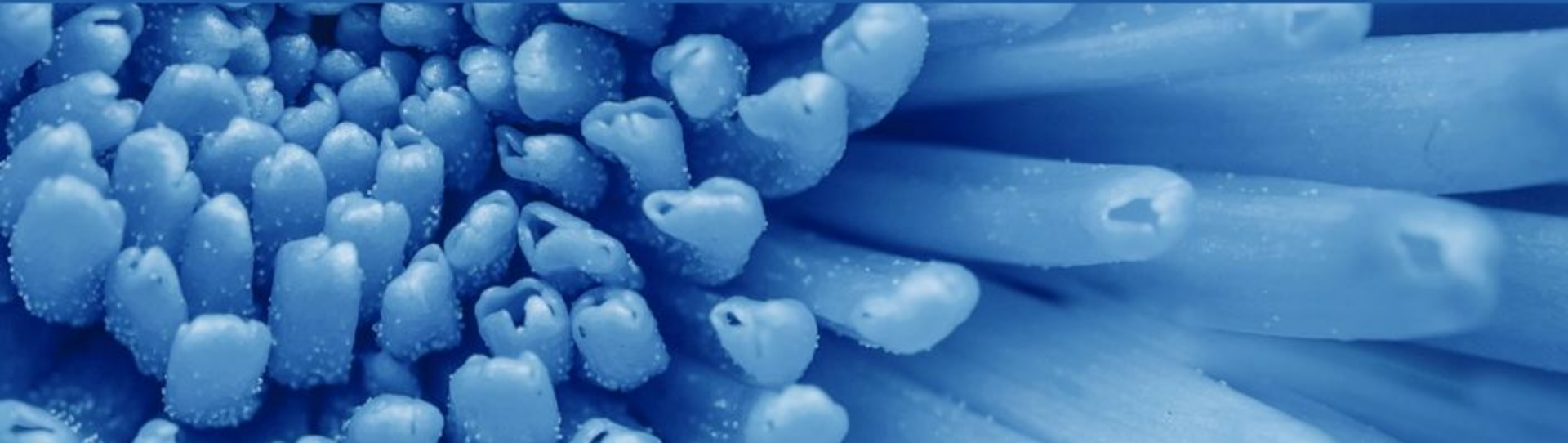


AI generates non-stop stream of death metal

by ENGADGET RSS FEED *on* APR 21, 2019

“In theory there is no difference between theory and practice. In practice there is.”

Yogi Berra



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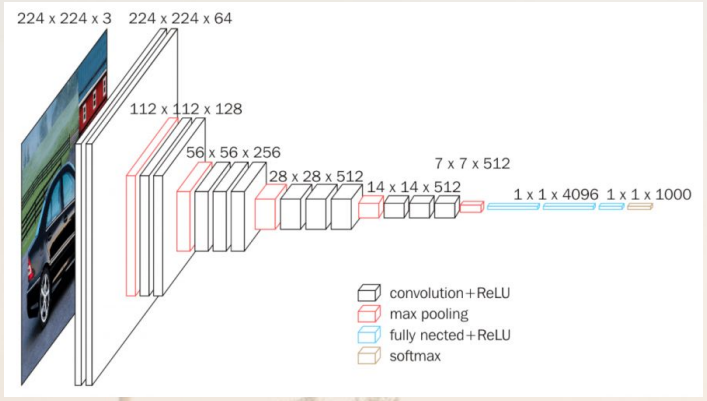
A Skateboard for the Pope

or

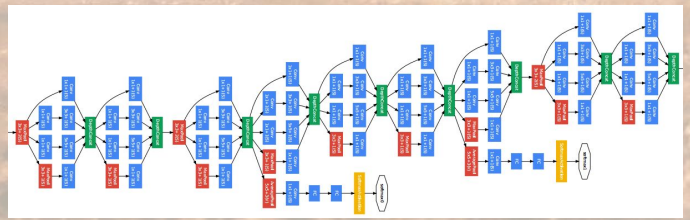
Why machine learning is doing so hard without SEMANTICS

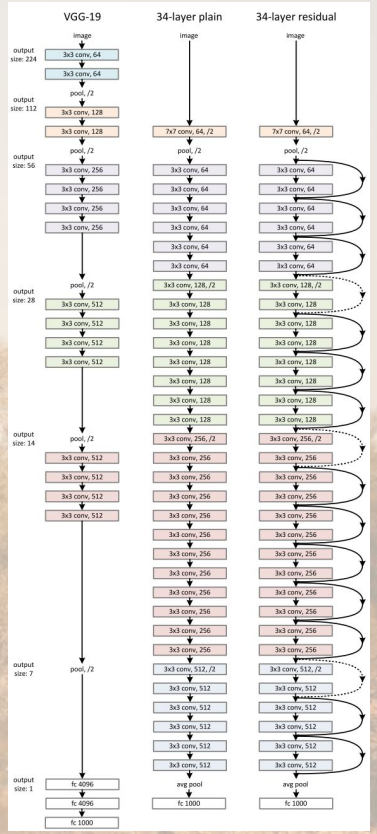
Abbot Hugo de Cluny, Margravine Mathilda of Tuscany and Henry IV, miniature from the manuscript *Vita Mathildis* (c 1115)

Experiment: Indexing with Pretrained State-of-the-Art Models



TensorFlow





Indexing with Pretrained State-of-the-Art Models

(1) Image Captioning (resnet50, 5m iterations)

```
0) a man standing in front of a microphone . (p=0.001874)
1) a man standing in front of a microphone holding a microphone . (p=0.000623)
2) a man in a suit and tie holding a microphone . (p=0.000467)
```

a man standing in front of a microphone .

(2) Visual Concept Detection (based on ImageNet 1K)

```
inception_v3: [[('n04296562', 'stage', 0.2797169), ('n03759954', 'microphone', 0.1635235), ('n04418357',
vgg16       : [[('n03372029', 'flute', 0.21658598), ('n03838899', 'oboe', 0.18556471), ('n04487394', 'tr
vgg19       : [[('n02879718', 'bow', 0.069563985), ('n04487394', 'trombone', 0.06794496), ('n03372029',
Resnet50    : [[('n02787622', 'banjo', 0.23410268), ('n03494278', 'harmonica', 0.09202912), ('n04286575'
Mobilenet_V2: [[('n02787622', 'banjo', 0.24096675), ('n04259630', 'sombrero', 0.07608573), ('n04487394',
Densenet    : [[('n03141823', 'crutch', 0.5543931), ('n03759954', 'microphone', 0.094545476), ('n0278762
NASAnet     : [[('n02787622', 'banjo', 0.40817854), ('n02676566', 'acoustic_guitar', 0.10958237), ('n042
```

Indexing with Pretrained State-of-the-Art Models

(1) Image Captioning (resnet50, 5m iterations)

```
0) a black and white photo of a man and a horse . (p=0.000597)
1) a black and white photo of a man with a horse . (p=0.000575)
2) a black and white photo of a man and a horse (p=0.000337)
```

a black and white photo of a man and a horse .

(2) Visual Concept Detection (based on ImageNet 1K)

```
inception_v3: [[('n03538406', 'horse_cart', 0.5826148), ('n03967562', 'plow', 0.2217709), ('n04604
vgg16       : [[('n03538406', 'horse_cart', 0.6929485), ('n03763968', 'military_uniform', 0.045812
vgg19       : [[('n03538406', 'horse_cart', 0.7175846), ('n03763968', 'military_uniform', 0.047984
Resnet50    : [[('n03538406', 'horse_cart', 0.3555997), ('n03763968', 'military_uniform', 0.312221
Mobilenet_V2: [[('n02403003', 'ox', 0.3520962), ('n03538406', 'horse_cart', 0.08434733), ('n038682
Densenet    : [[('n03538406', 'horse_cart', 0.75100106), ('n02403003', 'ox', 0.08875632), ('n03868
NASAnet     : [[('n03967562', 'plow', 0.87051934), ('n03538406', 'horse_cart', 0.09820043), ('n031
```

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Indexing with Pretrained State-of-the-Art Models

(1) Image Captioning (resnet50, 5m iterations)

```
0) a vase filled with flowers sitting on top of a table . (p=0.001639)
1) a vase filled with flowers sitting on a table . (p=0.001241)
2) a vase of flowers sitting on a table . (p=0.001143)
```

a vase filled with flowers sitting on top of a table .

(2) Visual Concept Detection (based on ImageNet 1K)

```
inception_v3: [[('n03991062', 'pot', 0.5503563), ('n01943899', 'conch', 0.061974872), ('n12620546', '
vgg16       : [[('n02840245', 'binder', 0.31984767), ('n07248320', 'book_jacket', 0.23865435), ('n032
vgg19       : [[('n03598930', 'jigsaw_puzzle', 0.39231554), ('n07248320', 'book_jacket', 0.20700723),
Resnet50    : [[('n03598930', 'jigsaw_puzzle', 0.31146914), ('n01943899', 'conch', 0.13275276), ('n04
Mobilenet_V2: [[('n03598930', 'jigsaw_puzzle', 0.66152334), ('n01667778', 'terrapin', 0.018356627), (
Densenet    : [[('n09256479', 'coral_reef', 0.21517044), ('n12985857', 'coral_fungus', 0.1408107), ('n
NASAnet     : [[('n01667778', 'terrapin', 0.37880373), ('n01669191', 'box_turtle', 0.15951602), ('n04
```

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Indexing with Pretrained State-of-the-Art Models

(1) Image Captioning (resnet50, 5m iterations)

```
0) a man sitting on a chair with a laptop . (p=0.000046)
1) a man sitting on a chair with a hat on . (p=0.000026)
2) a man sitting on a bench with a hat on . (p=0.000025)
```

a man sitting on a chair with a laptop .

(2) Visual Concept Detection (based on ImageNet 1K)

```
inception_v3: [[('n04532106', 'vestment', 0.8339432), ('n04429376', 'throne', 0.06276988), ('n04
vgg16       : [[('n03000247', 'chain_mail', 0.5499288), ('n02895154', 'breastplate', 0.08058794)
vgg19       : [[('n03045698', 'cloak', 0.23458833), ('n04532106', 'vestment', 0.16236556), ('n03
Resnet50    : [[('n04532106', 'vestment', 0.3460238), ('n03000247', 'chain_mail', 0.20139052), (
Mobilenet_V2: [[('n04532106', 'vestment', 0.27926844), ('n03000247', 'chain_mail', 0.10626966),
Densenet    : [[('n04532106', 'vestment', 0.5737181), ('n03045698', 'cloak', 0.04356383), ('n044
NASAnet     : [[('n04429376', 'throne', 0.40760532), ('n04532106', 'vestment', 0.2631193), ('n03
```

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Indexing with Pretrained State-of-the-Art Models

(1) Image Captioning (resnet50, 5m iterations)

```
0) a collage of photos of a person holding a skateboard (p=0.000002)
1) a collage of photos with a bunch of different pictures (p=0.000002)
2) a collage of photos of a person holding a skateboard . (p=0.000001)
```

a collage of photos of a person holding a skateboard

(2) Visual Concept Detection (based on ImageNet 1K)

```
inception_v3: [[('n06596364', 'comic_book', 0.29700932), ('n07248320', 'book_jacket', 0.21479161)
vgg16       : [[('n03291819', 'envelope', 0.80103236), ('n07248320', 'book_jacket', 0.12616517),
vgg19       : [[('n03291819', 'envelope', 0.71845376), ('n06596364', 'comic_book', 0.21161233), (
Resnet50    : [[('n03291819', 'envelope', 0.5337895), ('n06596364', 'comic_book', 0.20693506), ('
Mobilenet_V2: [[('n06596364', 'comic_book', 0.3172333), ('n03598930', 'jigsaw_puzzle', 0.16213572
Densenet    : [[('n03291819', 'envelope', 0.2729636), ('n06596364', 'comic_book', 0.19083193), ('
NASAnet     : [[('n03291819', 'envelope', 0.4995414), ('n03485794', 'handkerchief', 0.25641188),
```

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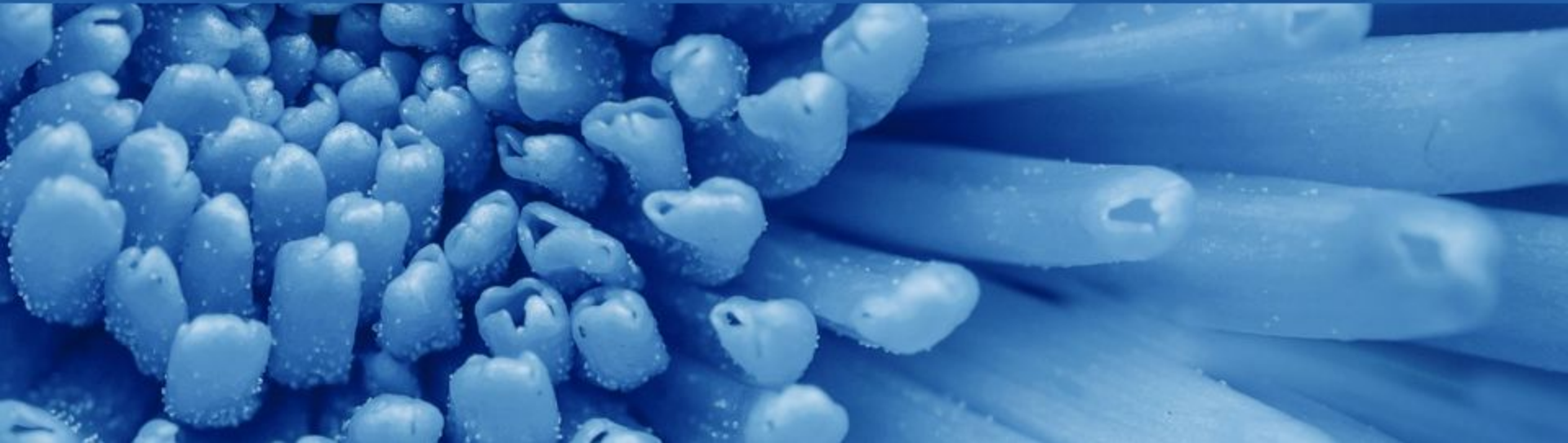
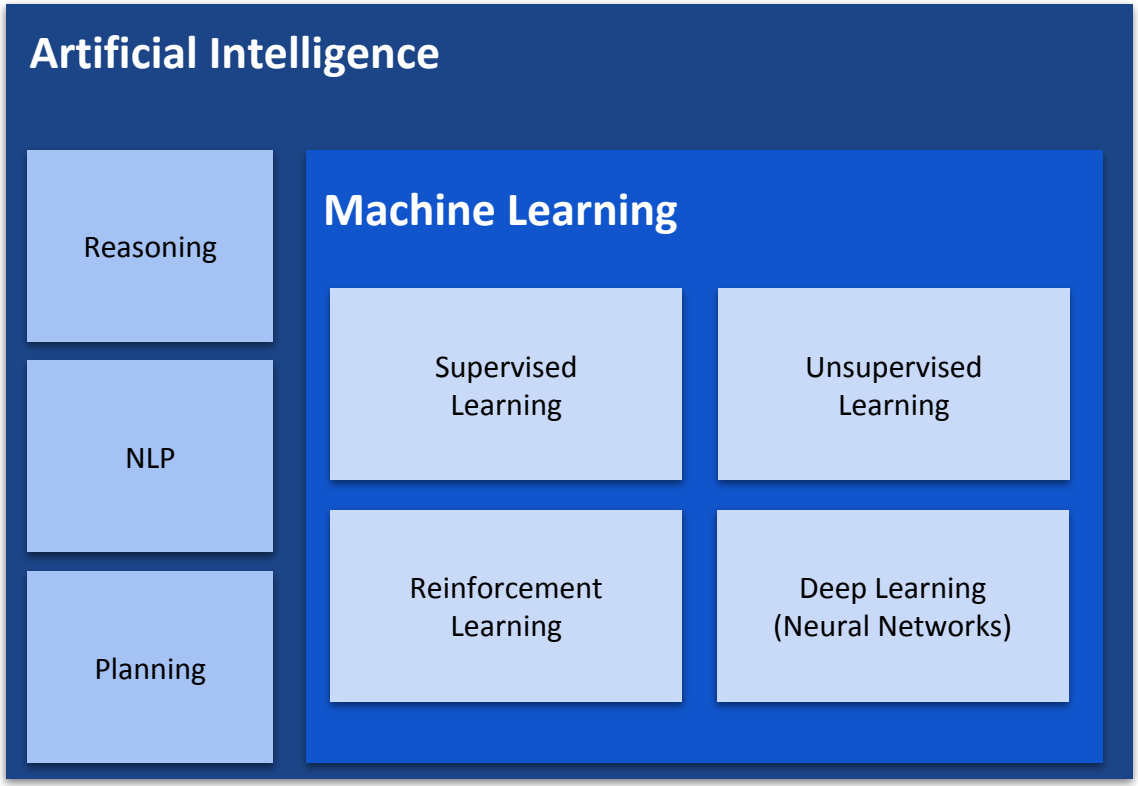
“I have not failed. I've just found 10,000 ways that won't work.”

Thomas A. Edison

as quoted in [J. L.] Elkhorne. Edison - The Fabulous Drone, in 73 Vol. XLVI, No. 3 (March 1967), p. 52

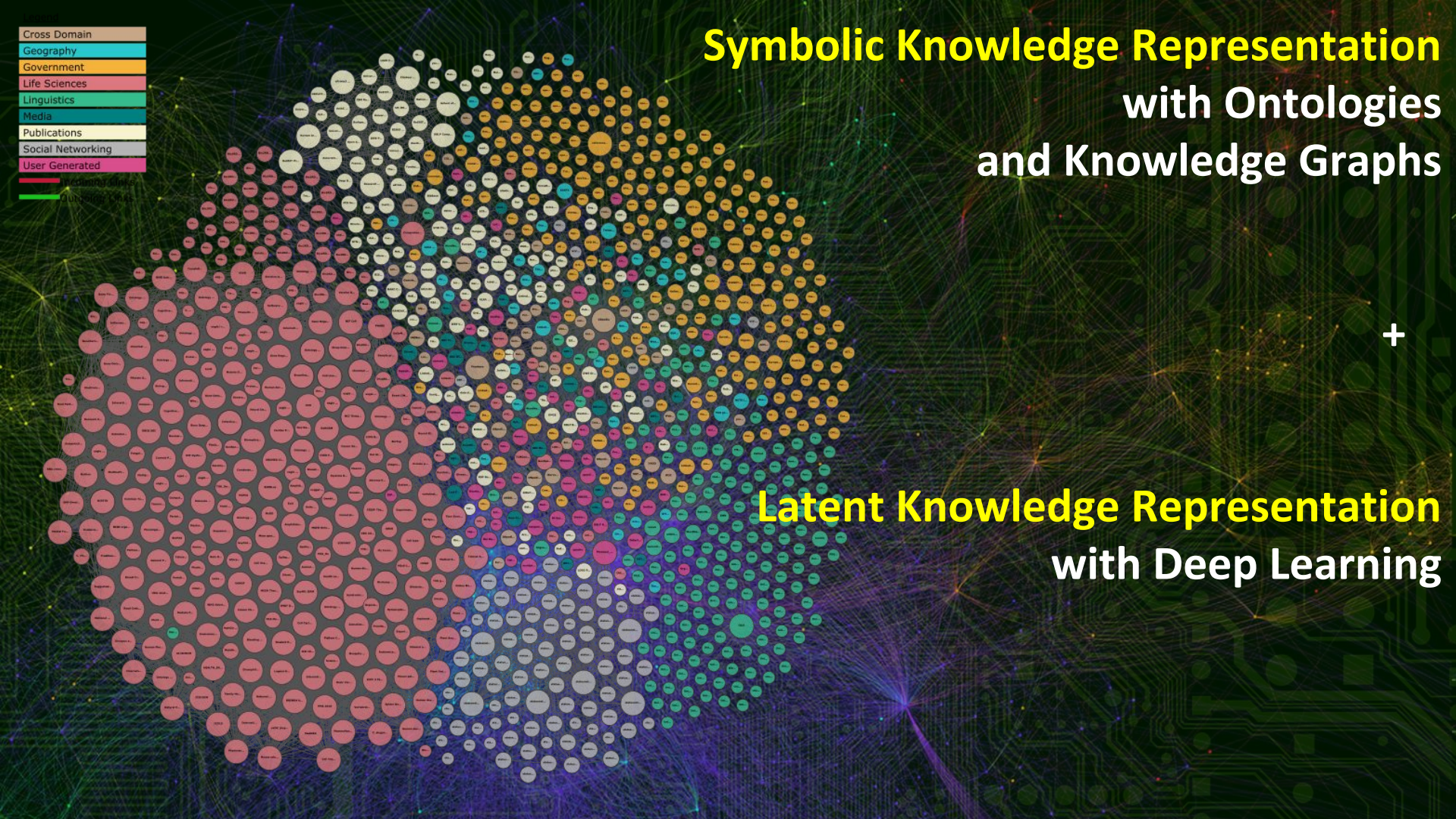


Artificial Intelligence is more than Machine Learning



"The Goal of AI is to develop machines that behave as though they were intelligent."

- John McCarthy (1955)


Legend
Cross Domain
Geography
Government
Life Sciences
Linguistics
Media
Publications
Social Networking
User Generated
Symbolic Knowledge Representation
with Ontologies
and Knowledge Graphs
+
Latent Knowledge Representation
with Deep Learning

Object Recognition

person

Fine Grain Object Recognition

black and white picture

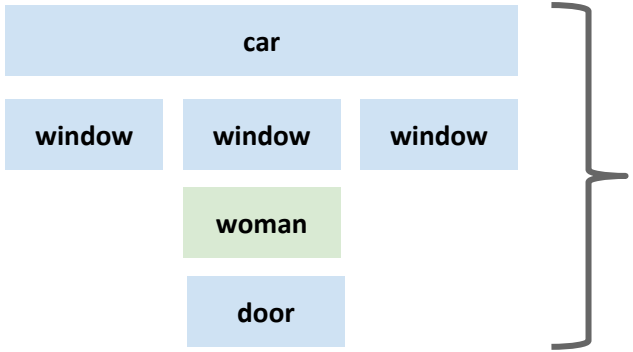
car

window | window | window

woman

door

Räumliche und semantische Analyse




```
Window    ⊑ ∃isPartOf.Car
Door      ⊑ ∃isPartOf.Car
Woman     ⊑ Person
Passenger ⊑ Person ⊓ ∃isTransportedBy.Car
...
```

External Knowledge

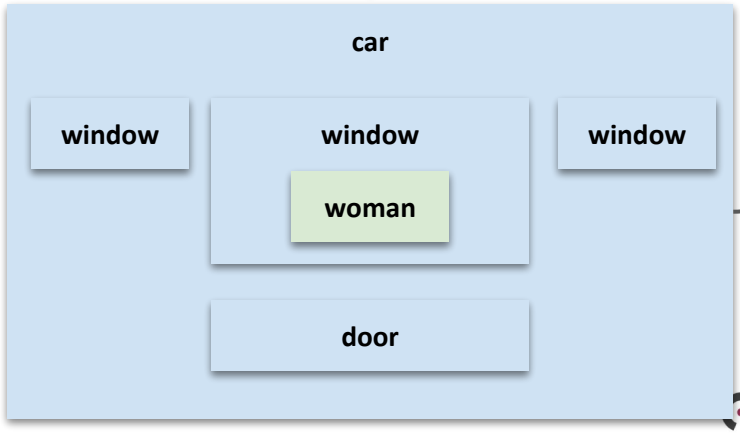


Image Captioning

car

window | window | window

woman

door

A black and white photo of a woman sitting in a car looking out the window

- a black and white picture of a woman
- a woman sitting in a car
- a woman looking out the window
- a car with a door
- a car with three windows

Question Answering

car

window | window | window

woman

door

A black and white photo of a woman sitting in a car looking out the window

Who is on the picture? **a woman**

Who is sitting in the car? **a woman**

```
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<Woman123>   <sittingIn> <Car123>
```
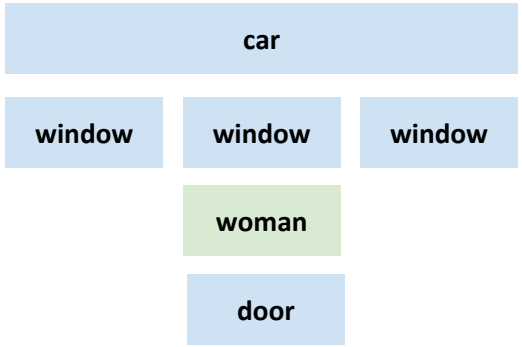
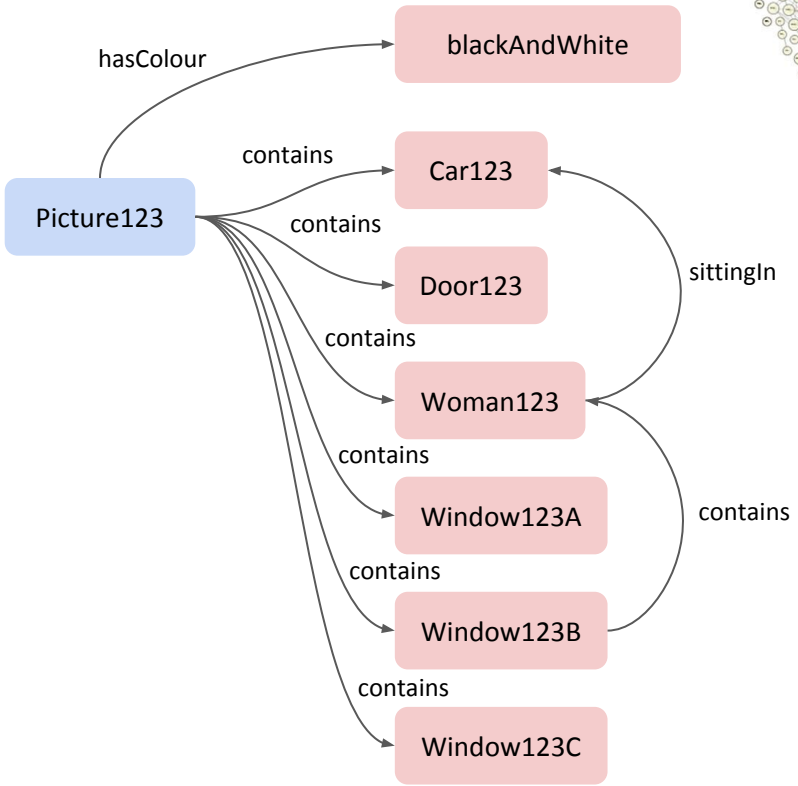
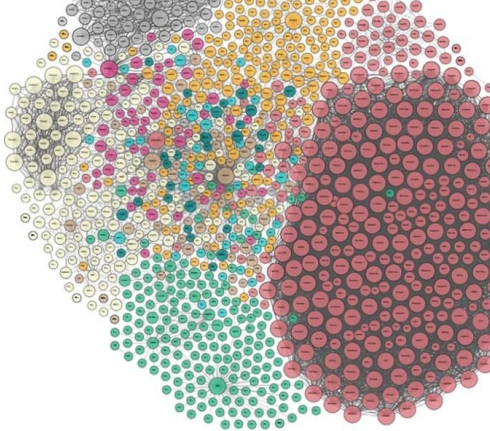

A Universe of Image Descriptions

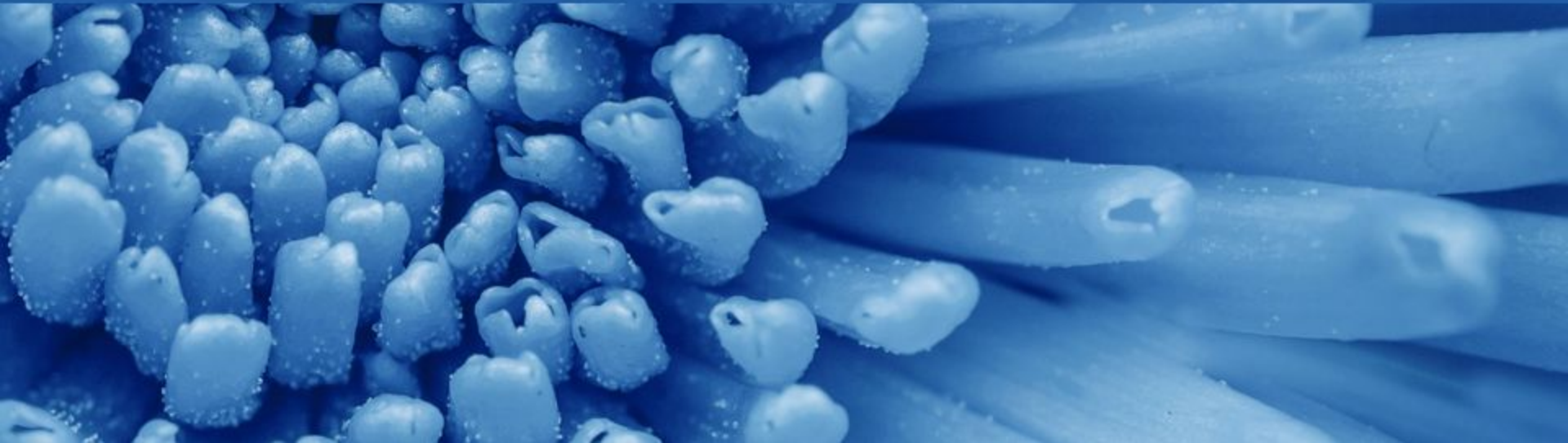






“All for one, one for all, that is our motto.”

Alexandre Dumas, The Three Musketeers, (1844)

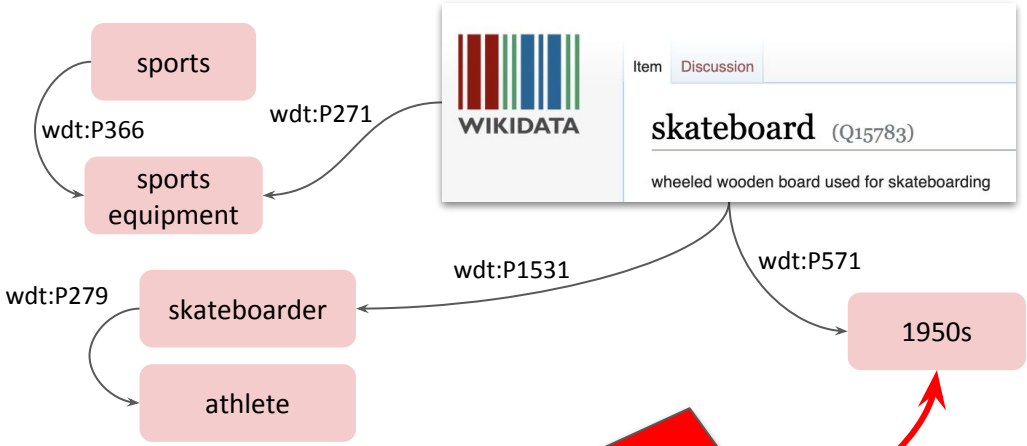


Combining Deep Learning and Semantics

Automated Image captioning:

a **person** holding a **skateboard**

Entity Linking



Metadata

title:	Vita Mathildis
author:	Donizio
date:	**1115**
location:	Bibliotheca Apostolica Vaticana...

Combining Deep Learning and Semantics

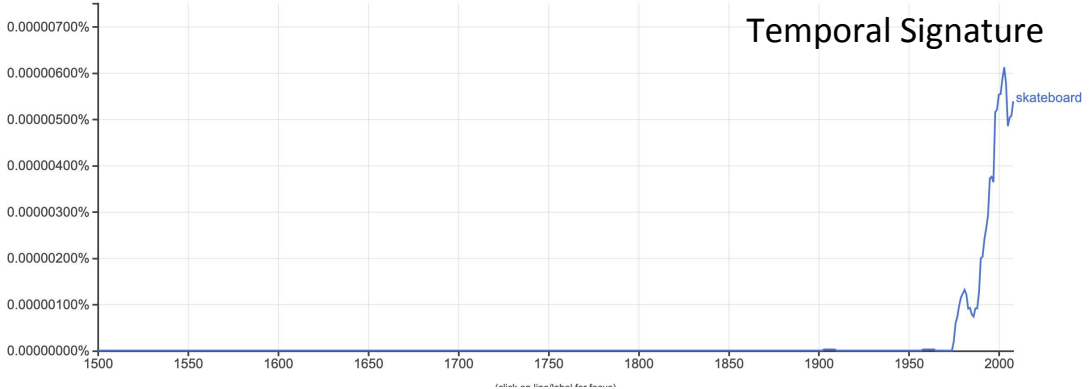
Automated Image captioning:

a **person** holding a **skateboard**

Entity Linking

At two spots in the world a kind of a **skateboard** was developed at **the first** time in **the early** 1950s: California and Hawaii. They used shorter surfboards and wheels made out of metal without some bearings. In the late 1950s, **skateboarding** had **a first** peak.

Temporal Signature



Knowledge Graph Based Exploration

FIZ Karlsruhe
Leibniz-Institut für Informationsinfrastruktur

Karlsruher Institut für Technologie

Timeline | 205 results in 1633 ms | Code | Download | Link

1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000

7 August 1946 Fausto Vitello

23 August 1945 Patti McGee

10 April 1956 Peggy Oki

11 June 1961 Andy Kessler

16 January 1960 Steve Rocco

30 May 1958 Ty Page

9 January 1958

28 October 1964 Joe Lopes

17 August 1966 Rodney Mullen

11 October 1971 Jason Ellis

5 October 1971 Ray Barbee

19 October 1976 Darren Navarette

10 October 1976 Bob Burnquist

7 October 1976

12 June 1976 Brian Anderson

1 February 1977 Jeron Wilson

6 January 1977 Marc Johnson

10 March 1982 Chris Cole

4 July 1981 Dan Joyce

13 May 1982 Edgard Pereira

Arto Saari

17 December 1981 Jerry Hsu

31 January 1987 Lucas Puig

28 April 1988 Sebo Walker

26 October 1991 TJ Rogers

6 December 1992 Riley Hawk

14 July 1987 Patrick Switzer

26 May 1988 Dylan Rieder

19 August 1988 Antwuan Dixon

15 February 1989 Brandon Westgate

27 March 1992 Kevin Kowalski

13 April 1993 Letícia Bufoni

19 June 1998 Joey Jett

14 September 1999 Tom Schaar

30 November 1994 Nyjah Huston

10 January 1996 Curren Caples

20 February 1997 Mitchie Brusco

At two spots in the world a kind of a **skateboard** was developed at **the first** time in **the early** 1950s: California and Hawaii. They used shorter surfboards and wheels made out of metal without some bearings. In the late 1950s, **skateboarding** had **a first** peak.

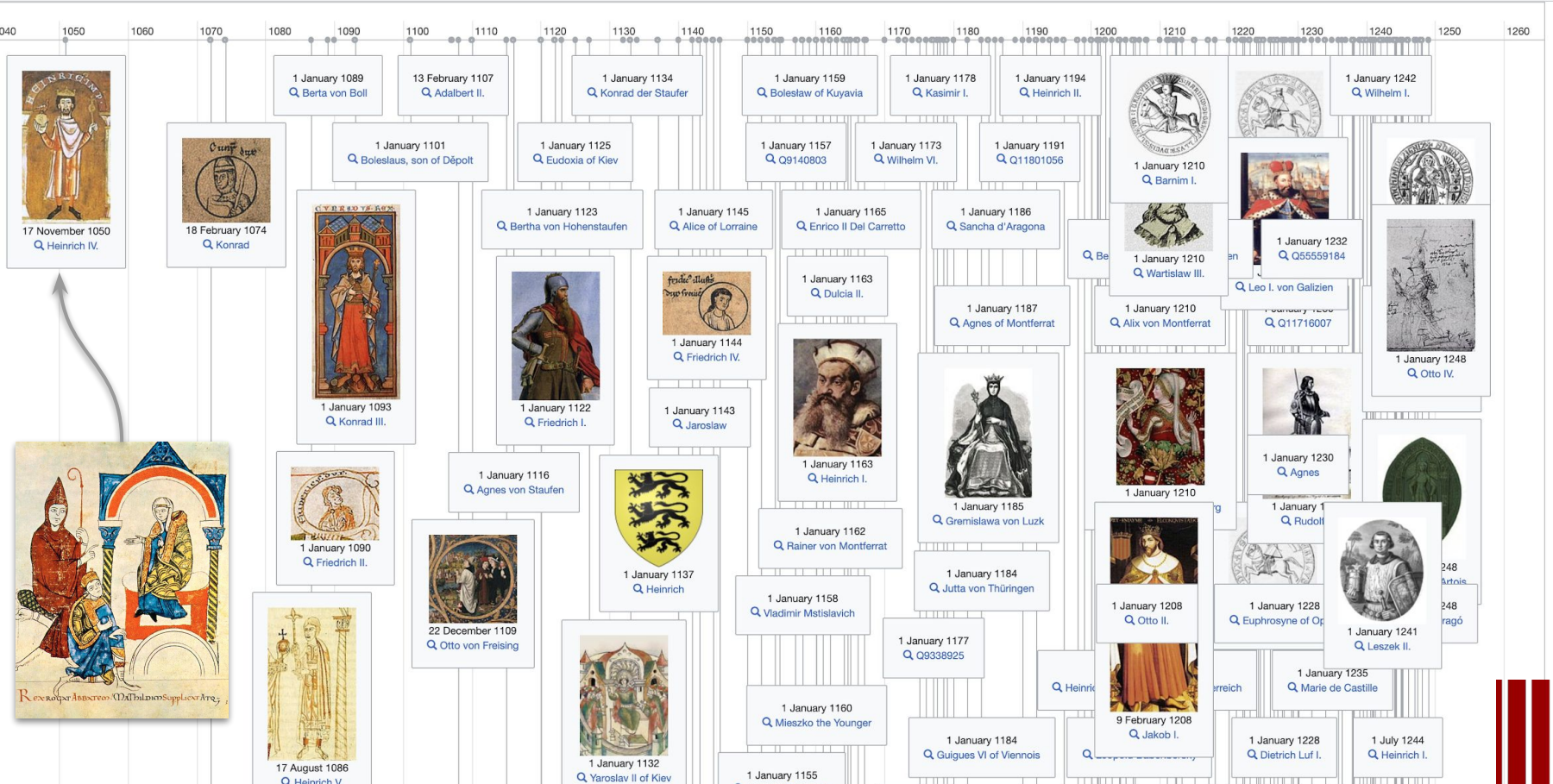
Knowledge Graph Based Exploration

FIZ Karlsruhe
Leibniz-Institut für Informationsinfrastruktur

KIT
Karlsruher Institut für Technologie

Timeline https://w.wiki/CTM

339 results in 12390 ms



Knowledge Graph Based Exploration

FIZ Karlsruhe
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Karlsruher Institut für Technologie

Q4060918
Q11398608
Yaroslav II of Kiev
Friedrich IV.
Kasimir I.
Richardis von Babenberg
Agnes von Österreich
Béla, Heir of Hungary
Q11801056
Heinrich
Heinrich II.
Judith de Lorraine
Q9140803
Boleslaw I.
Konrad III.
Mieszko I.
Stephan III.
Q933892
Beatrice of Auxonne
Ludmilla von Böhmen
Agnes of Bohemia
Adalbert III. von Böhmen
Jaroslaw
Konrad II. von Babenberg
Johann I.
Boleslaus, son of Dépolt
Balduin V.
Berta von Boll
Agnes von Babenberg
Dulcia II.
Gertrude von Babenberg
Friedrich
Sophie von Böhmen
Heinrich II.
Hedwig von Lothringen
Beatrice, Countess of Chalon
Konrad
Anna von Burgund, Gräfin von Savoyen
Ottone del Carretto, Marquis of Savona
Enrico II Del Carretto
Adalbert II.
Agnes von Waiblingen
Heinrich IV.
Leonor de Aragón
Ferdinando d'Aragona
Wilhelm von Montferrat
Vladimir Mstislavich
Richenza von Everstein
Heinrich V.
Beatrix
Beatrice del Monferrato
Azalaïs of Montferrat
Leopold
Sancha d'Aragona
Guigues VI of Viennois
Jutta von Babenberg
Mstislaw II.
Roman
Sancha von Kastilien
Beatrice Schwäbische
Otto von Freising
Ladislaus III.
Ferdinand of Castille
Peter II.
Konstanze von Aragón
Ambrogio Del Carretto
Bonifacio I
Konrad
Wsewolod Mstyslawytsch
Alfons II.
Rainer von Montferrat
Cunigunda of Lorraine
Heinrich IV.
Friedrich V. von Schwaben
Vsevolod Vsevolodovich
Maria von Montferrat
Bonifatius I.
Heinrich VI.
Vasylko Yaropolkpvych
Friedrich II.

https://w.wiki/CTJ

Knowledge Graph Based Exploration

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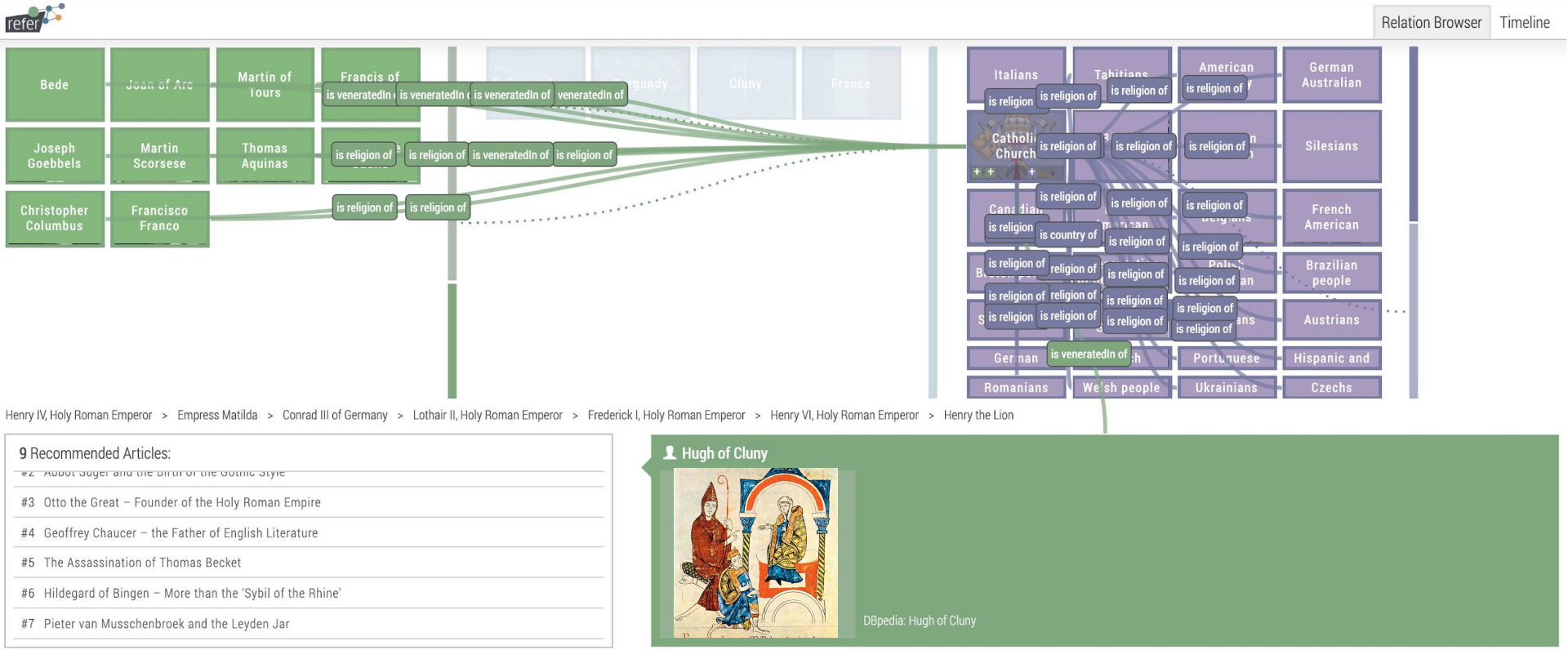
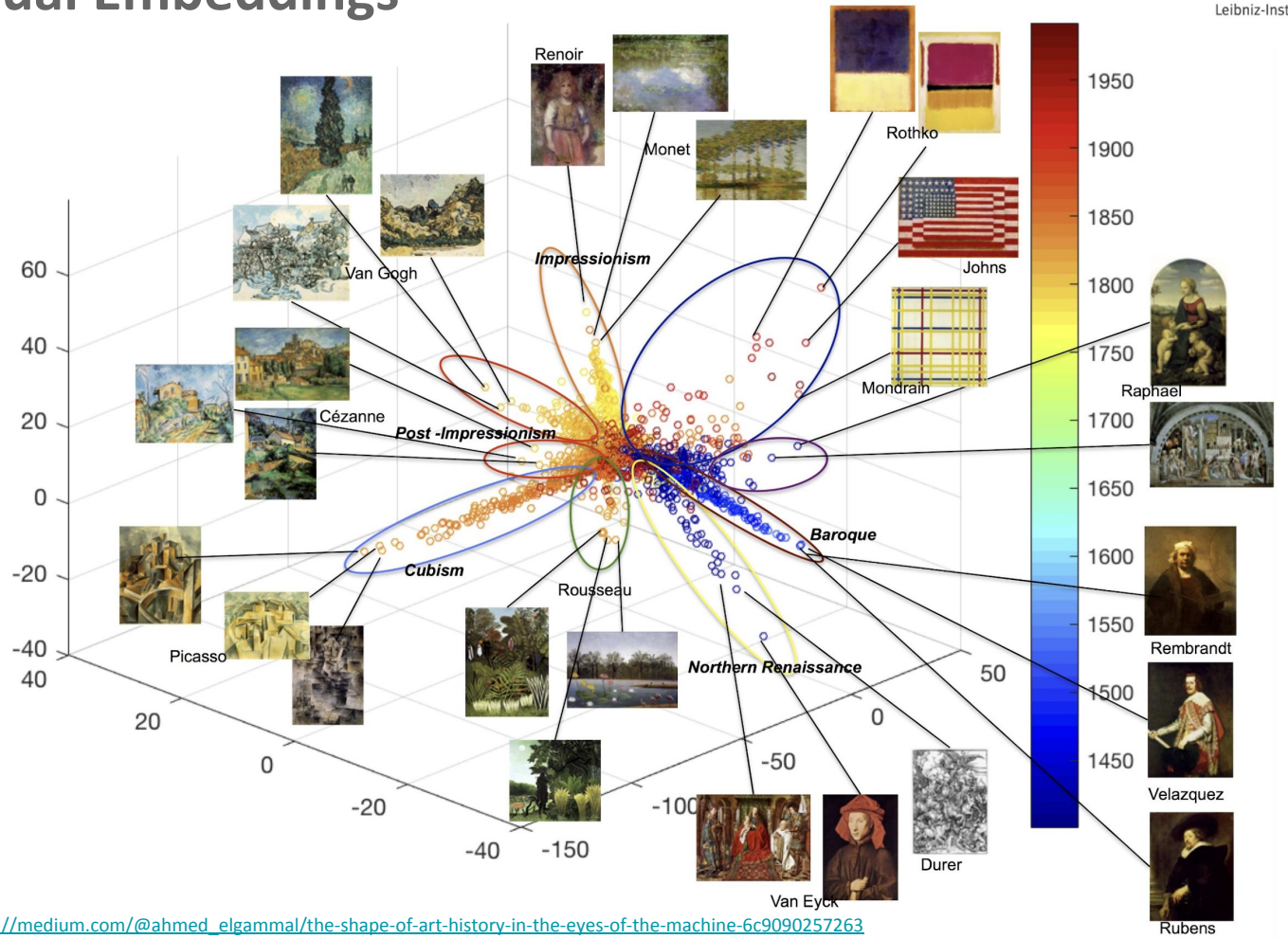


http://scihi.org/

Visual Embeddings



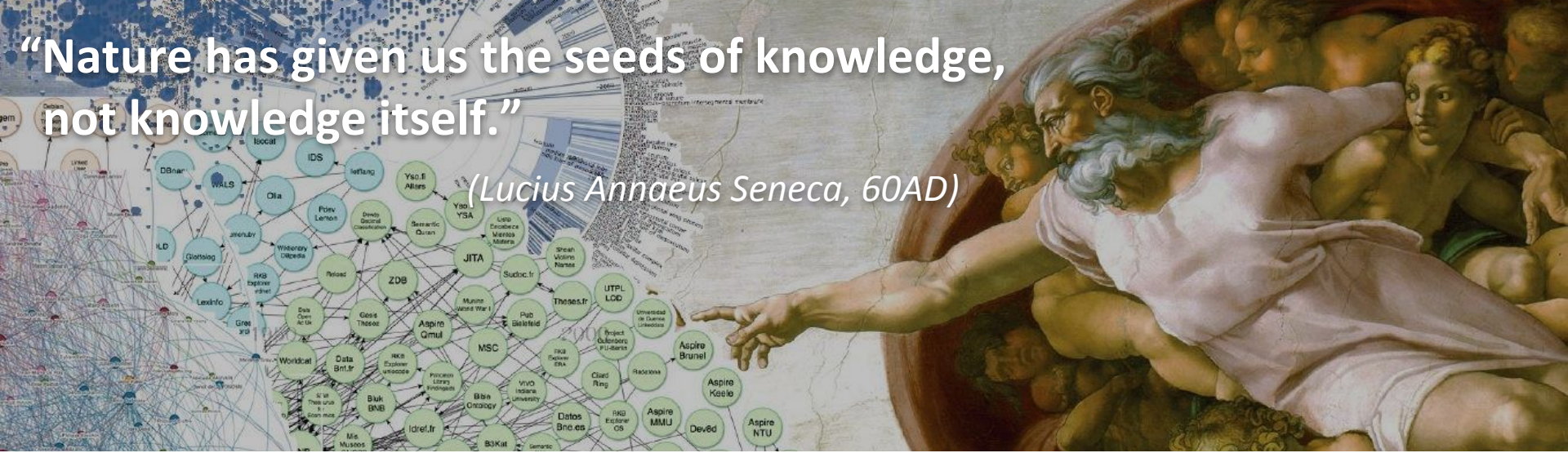
https://medium.com/@ahmed_elgammal/the-shape-of-art-history-in-the-eyes-of-the-machine-6c9090257263

Similarity Based Search and Exploration

https://wikiview.net/

Take Home Messages:

- Deep Learning is a **game changer**
- The quality of your achieved results always depends on the quality (and quantity) of your **training data**
- Out-of-the-box Deep Learning models are **easy to use and work quite well** (well...most of the time)
- **Deep Learning benefits from exploiting semantics**



Prof. Dr. Harald Sack

Artificial Intelligence for Cultural Heritage

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twitter: lysander07

Europeana 2019
Lisbon, 27. Nov. 2019

Karlsruher Institut für Technologie

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