

Creative AI, an Hour and a Half Trip Through Dogs, Monet and Antennas

1st AlforPeople Workshop

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About me



- PhD Student @ University of Bologna (Italy).
- Head of AI research @ AlforPeople
- Teaching Assistant of the course Algorithms and Data Structures @ Unibo.
- Board Member of Data Science Bologna.
- Proud Member of *ContinualAI*.
- Amateur Astronomer @ Astrofili Cesenati.

Outline

- 1 What is creativity?
- 2 Dogs, or what a neural network dreams when it sleeps and how to teach it to paint.
- 3 Monet, or generative model at the rescue and how to teach a neural network to paint better and with its own style.
- 4 Antennas, or using artificial intelligence to create things that we cannot think.
- 5 Closing remarks and Q&A.

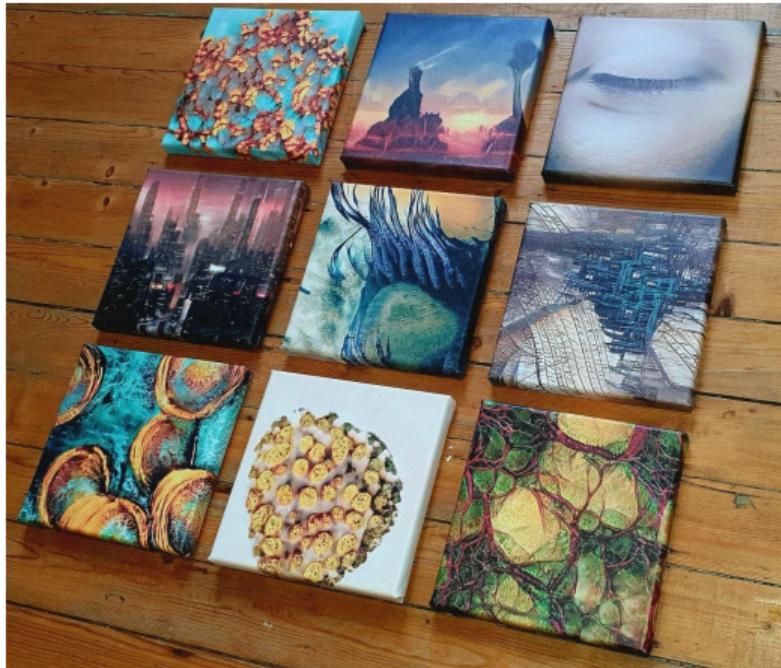
What is creativity?

The ability to produce original and unusual ideas, or to make something new or imaginative.
Cambridge Dictionary.

Keywords

- Produce.
- Original.
- Unusual.
- Make something new.

Examples of creativity



¹Image from Twitter

Examples of creativity

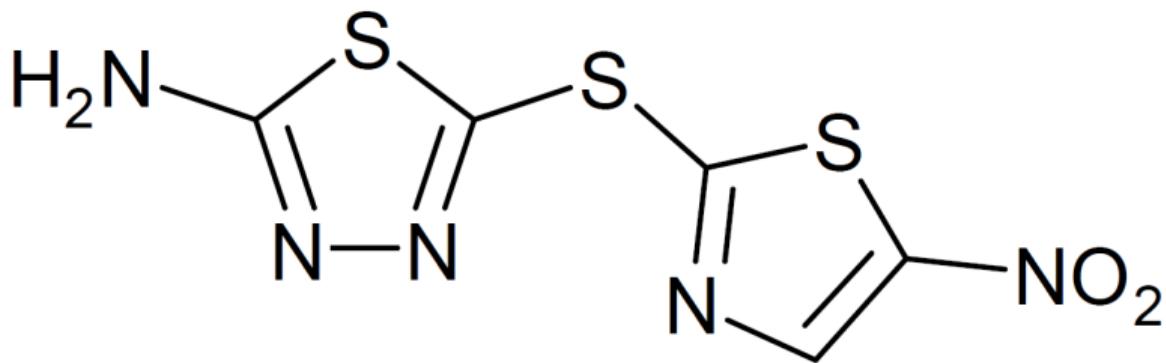
*With joyous gambols gay and still array,
no longer when he 'twas, while in his day
at first to pass in all delightful ways
around him, charming, and of all his days.*

Examples of creativity



²Image from adweek.com

Examples of creativity



Halicin

²Image from Wikipedia

Two types of AI creativity

AI as a tool for creativity

- The creative process is controlled by the human.
- Creativity resides in the human brain.
- AI is simply a tool, not different from the paintbrush for a painter.

AI as a creative entity

- No control on the results or the process.
- We cannot predict what the AI will produce.
- Creativity resides in the AI itself (or in the algorithm).
- More powerful but less controllable.

Dogs



³Image from Kevin Dooley Flickr profile.

Let's start our journey...

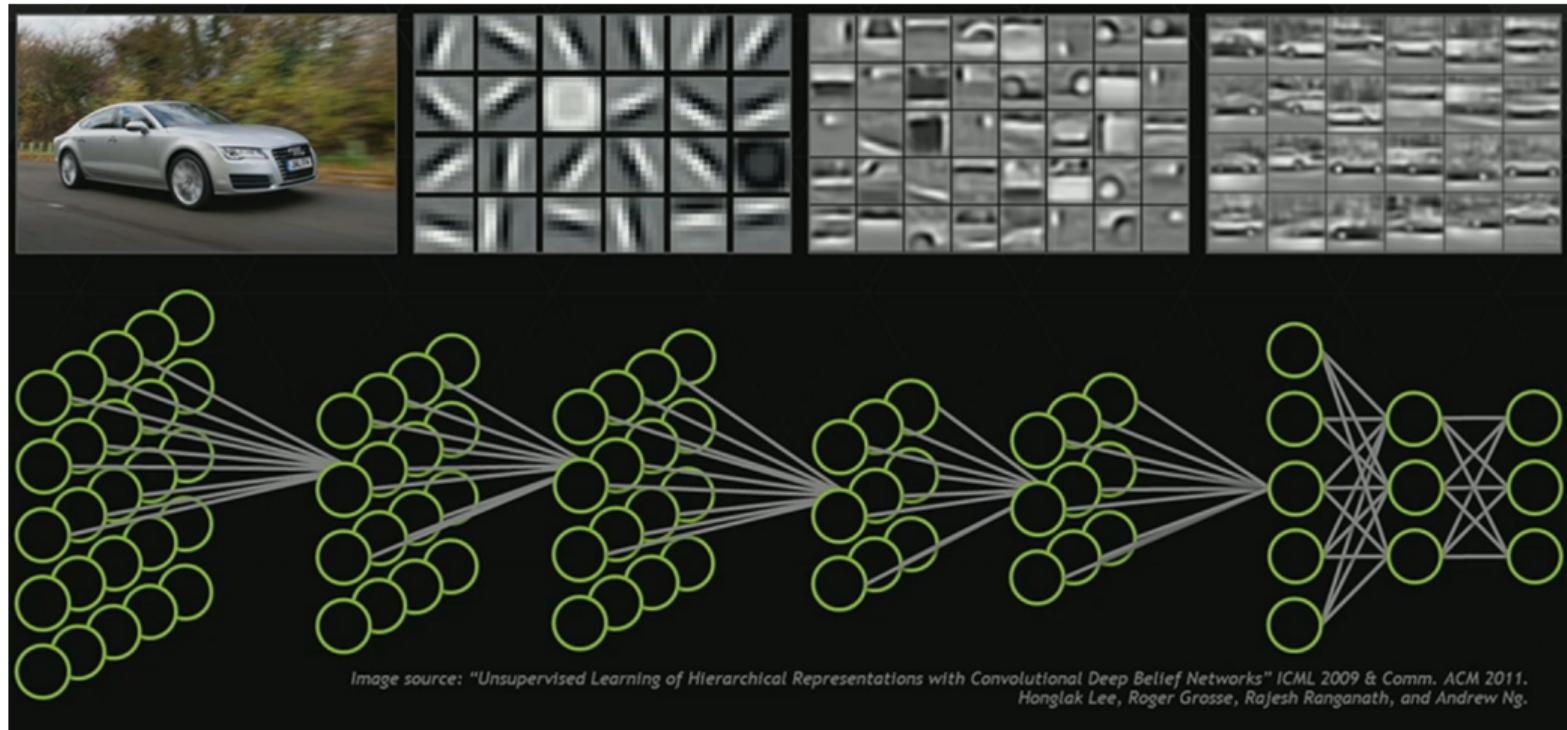
Once upon a time in 2012...

- 2012 was arguably the turning point for AI and machine learning.
- AlexNet by Alex Krizhevsky *et al.* won the 2012 ImageNet challenge by a large margin, improving the previous year result by more than 10 points.
- The deep learning era had begun.

Some time later...

- CNNs were used for many computer vision tasks (mainly classification).
- Great hype around them.
- Scientists started to ask why CNNs are so good, and what they learn internally.

Watch inside the brain of a computer



See dogs in the clouds

What do you see when you turn out the light?

- Scientists wanted to analyze the behavior of the network, so they choose a particular neuron (associated with a significant pattern) and maximize the response of the neuron changing the input.
- In simpler words, they asked to the network to imagine which image maximize the chosen feature.
- In more simpler words, they asked the network to imagine a dog.

See dogs in the clouds

Constellations and clouds

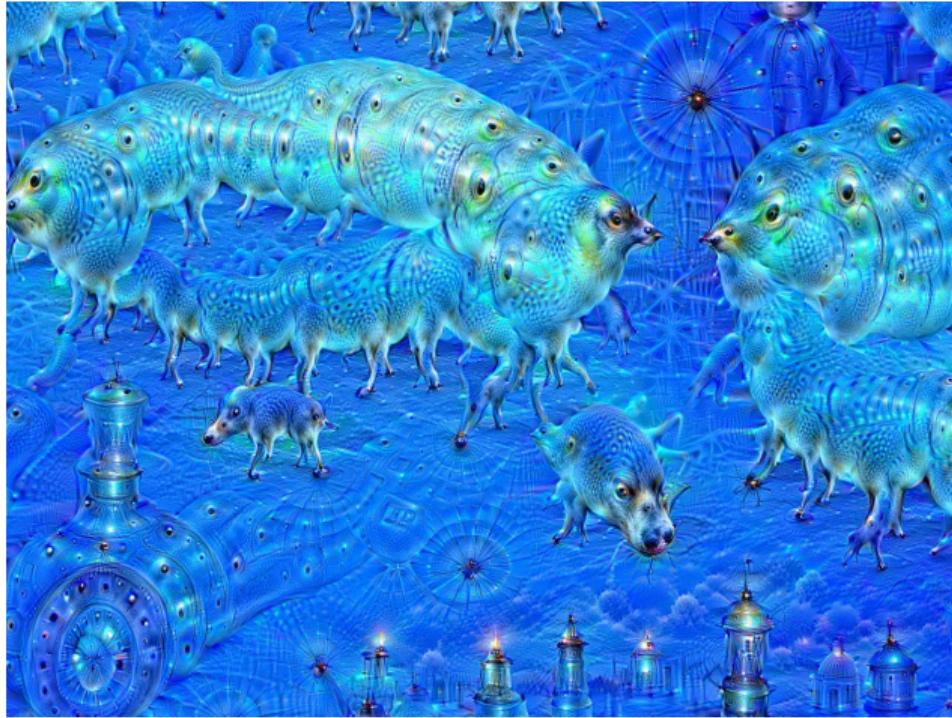
- Without any realistic input the network failed to imagine a realistic image (we'll return on this task later).
- So, what if a real image is used as a starting point and we ask to the network to edit it in order to maximize some internal feature?
- In simpler words, we are asking the network to see something that is not in the image (like we do when we watch clouds or stars).

See dogs in jellyfish



⁴Image from Wikipedia

See dogs in jellyfish



⁵Image from Wikipedia

See dogs in jellyfish



⁶Image from Wikipedia

Details

Technical

- SGD is used, but the network's weights are fixed, the input image is the target.
- The process is reiterated many times.

Trivia

- The images are similar to hallucinogens-induced hallucinations. This fact may suggest a functional resemblance between artificial neural networks and particular layers of the visual cortex.
- It was a vision of the world through the eyes of the machine. – Alexander Mordvintsev.
- This algorithm is called DeepDream, and it was one of the first use of AI to generate creative content.

Other examples



⁷Image from DeviantArt.com

Others examples



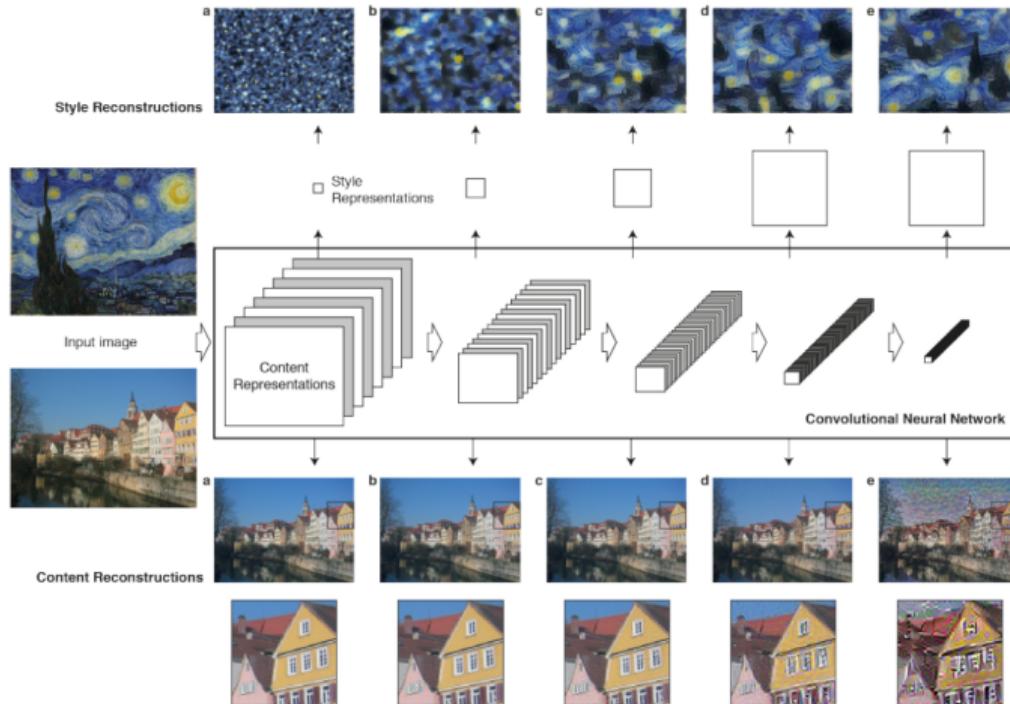
⁸Image from stichtingopen.nl

Cool, but we are tired of dogs.

What if we want to control the style of the generated images?

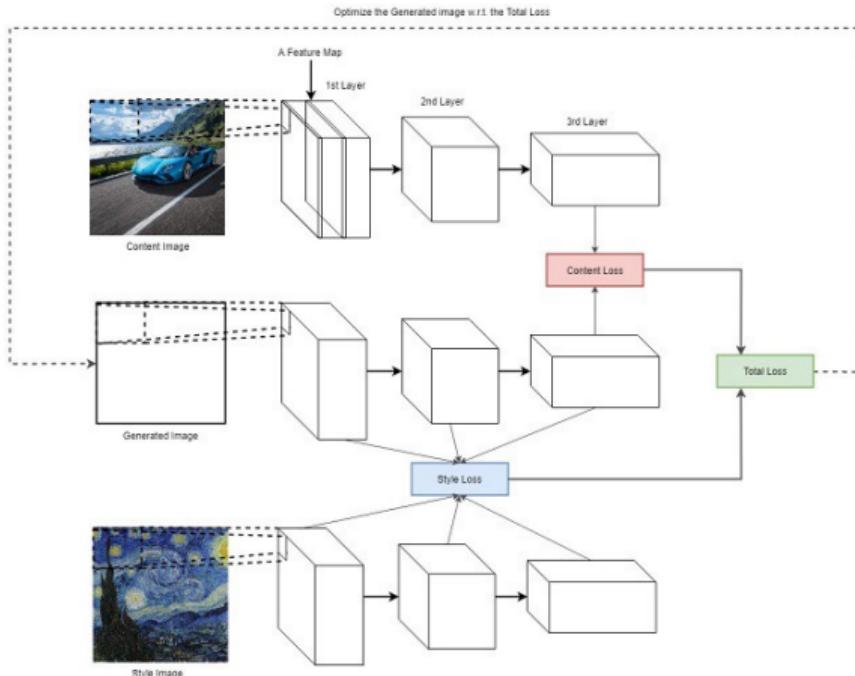
- In deep dream we have no control over the results.
- We want to produce images in a certain style, but maintaining the same content of the original image.
 - ▶ E.g. Apply the style of the Van Gogh's Starry Night to my photographs.
- We have to find a way to enforce our result to have the content of one image but the style of another.
 - ▶ But...what is style?
 - ▶ And how we can teach to a neural network *style*?

Neural Style Transfer



⁹Image from A Neural Algorithm of Artistic Styles, Leon A. Gatys et al. 2016

Neural Style Transfer



¹⁰Image from Intuitive Guide to Neural Style Transfer, Thushan Ganegedara (on Medium)

Details

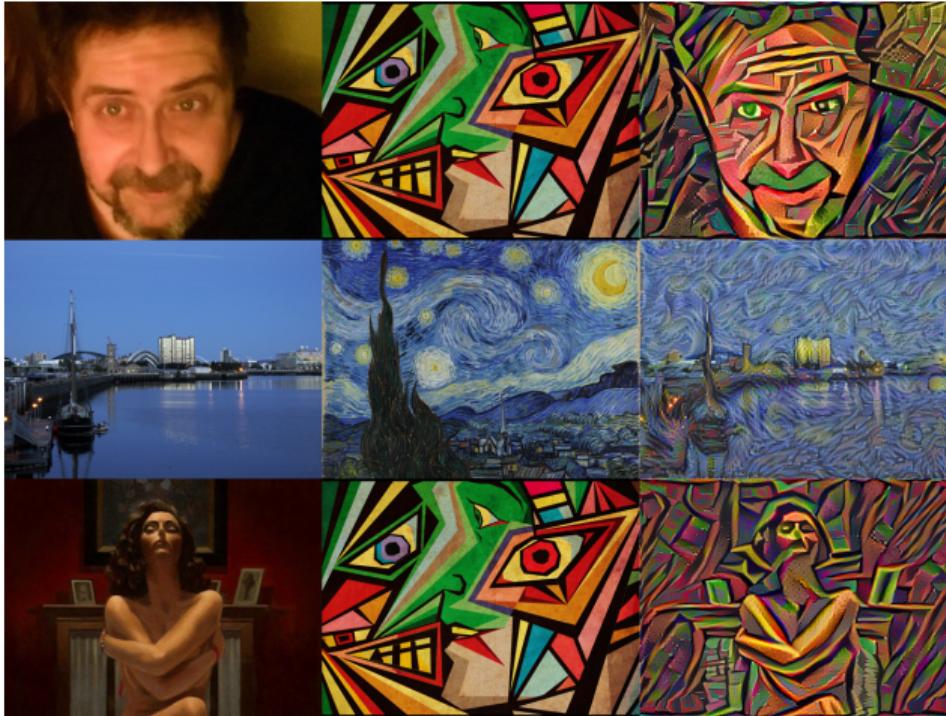
$$\mathcal{L}_{content}(\vec{p}, \vec{x}, l) = \frac{1}{2} \sum_{i,j} (F_{ij}^l - P_{ij}^l)^2$$

$$G_{ij}^l = \sum_k F_{ik}^l F_{jk}^l \quad (\text{Gram Matrix})$$

$$E_l = \frac{1}{4N_l^2 M_l^2} \sum_{i,j} (G_{ij}^l - A_{ij}^l)^2$$

$$\mathcal{L}_{style}(\vec{a}, \vec{x}) = \sum_{l=0}^L w_l E_l$$

Neural Style Transfer



¹¹Image from data-analyst.org

Neural Style Transfer



¹²Image from Neural Style Transfer on Real Time Video, Sourish Dey (on Medium)

Neural Style Transfer



Original Photo



Example Photo



Result

¹³Image from Deep Photo Style Transfer, Fujun Luan et al. 2017

Q&A

Monet



¹⁴Image from Musée d'Orsay (FR).

Monet



Images from CycleGAN project page

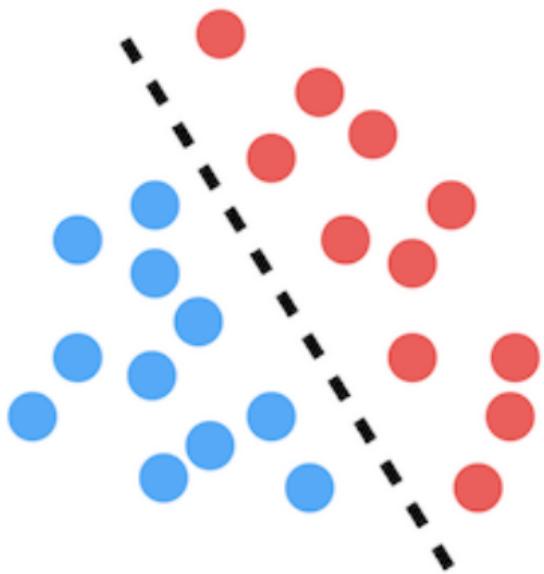
Limitation of Neural Style Transfer

- Slow, many forward and backward passes to edit the generated image.
- Limited, can only copy the style of one single image, not of a painter or an artistic style.
- Can only be used for images.
- The neural network is just a tool to extract some information about content and style, it does not generate anything.

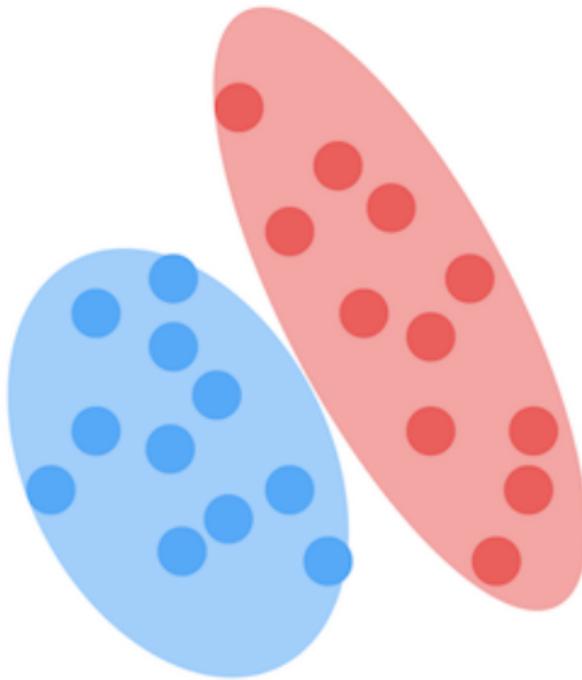
How can we teach a neural network to generate Monet's paintings or poetry?

Generative Models

Discriminative



Generative

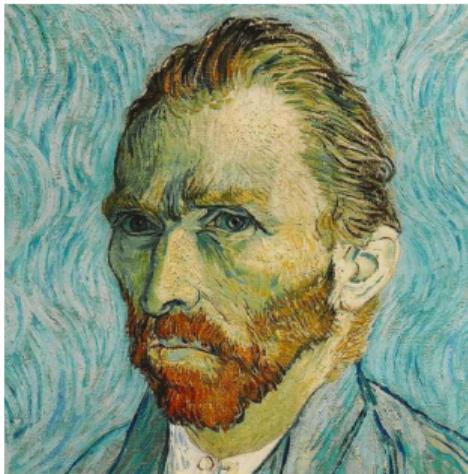
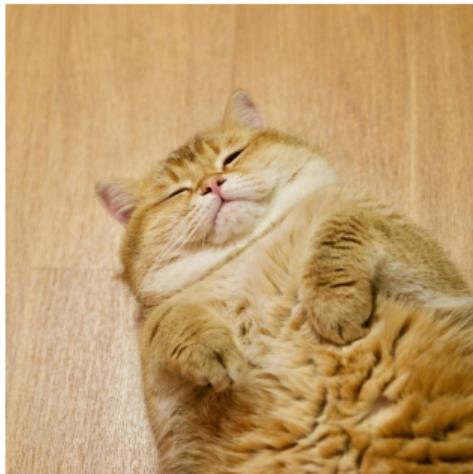


The problem with generating data

- Estimating a probability distribution from data points is almost impossible in high-dimensional space (a pretty small color image of 256×256 pixels has 196,608 dimensions!).
- Some generative models do not directly estimate the data probability (implicit density estimation) but they learn to generate data similar to the training data.
- This last category of models is appealing, but how we can estimate similarity between data?
- In other words, how can we mathematically define the concept of *how much a generated data is real?*

What is reality? I

How can we mathematically define how much an image of a cat is real? How can we define the concept of *catness*? And the concept of *van goghness*? Or the concept of *Trumpness*?



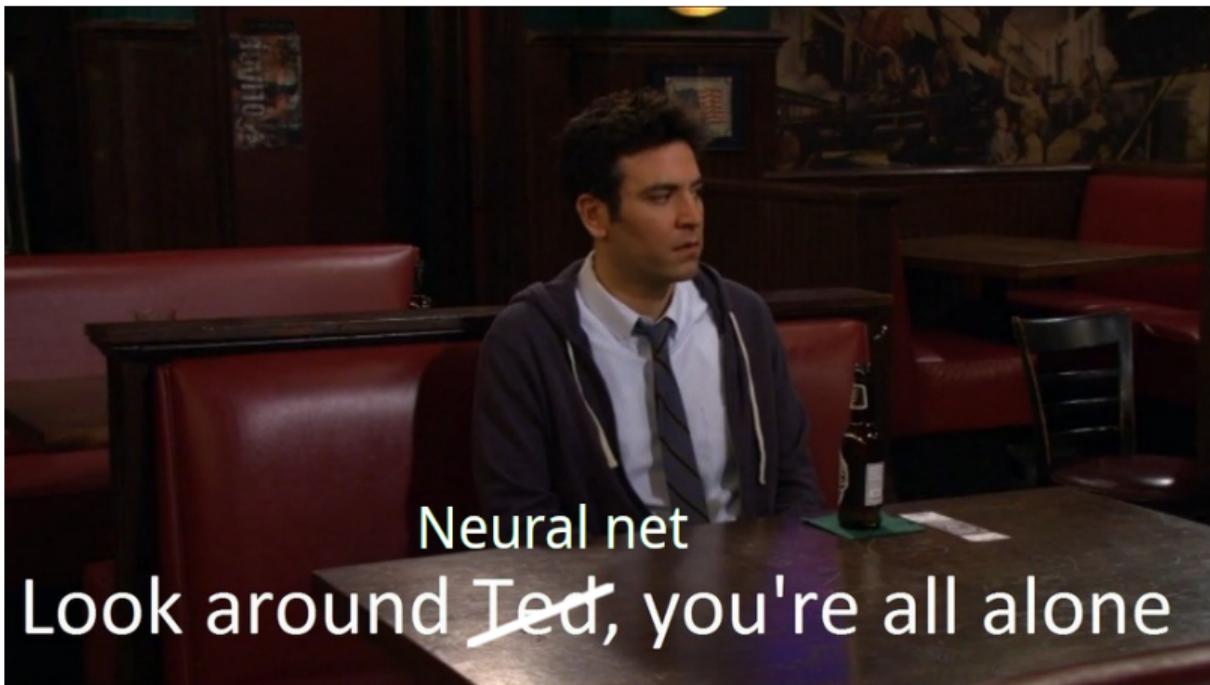
¹⁵Image from Hosico cat's Instagram profile, victorVanGogh.com and BBC.com

What is reality? II

We have seen **a lot** of cats in our life, so our brain have modeled some sort of statistical model that describes *how a cat looks like*. The same for Van Gogh portraits or images of Donald Trump.

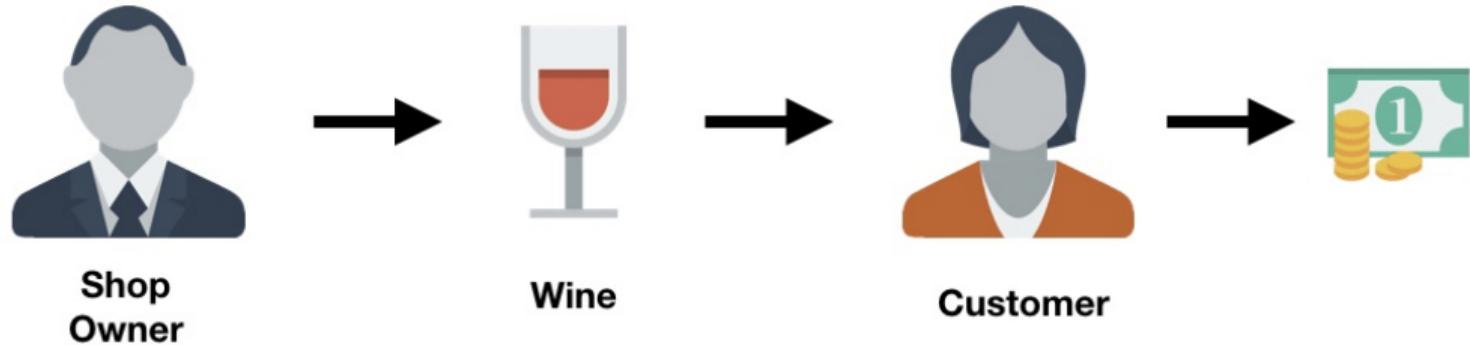


The problem with neural nets...



¹⁶Image from How I Met Your Mother, CBS

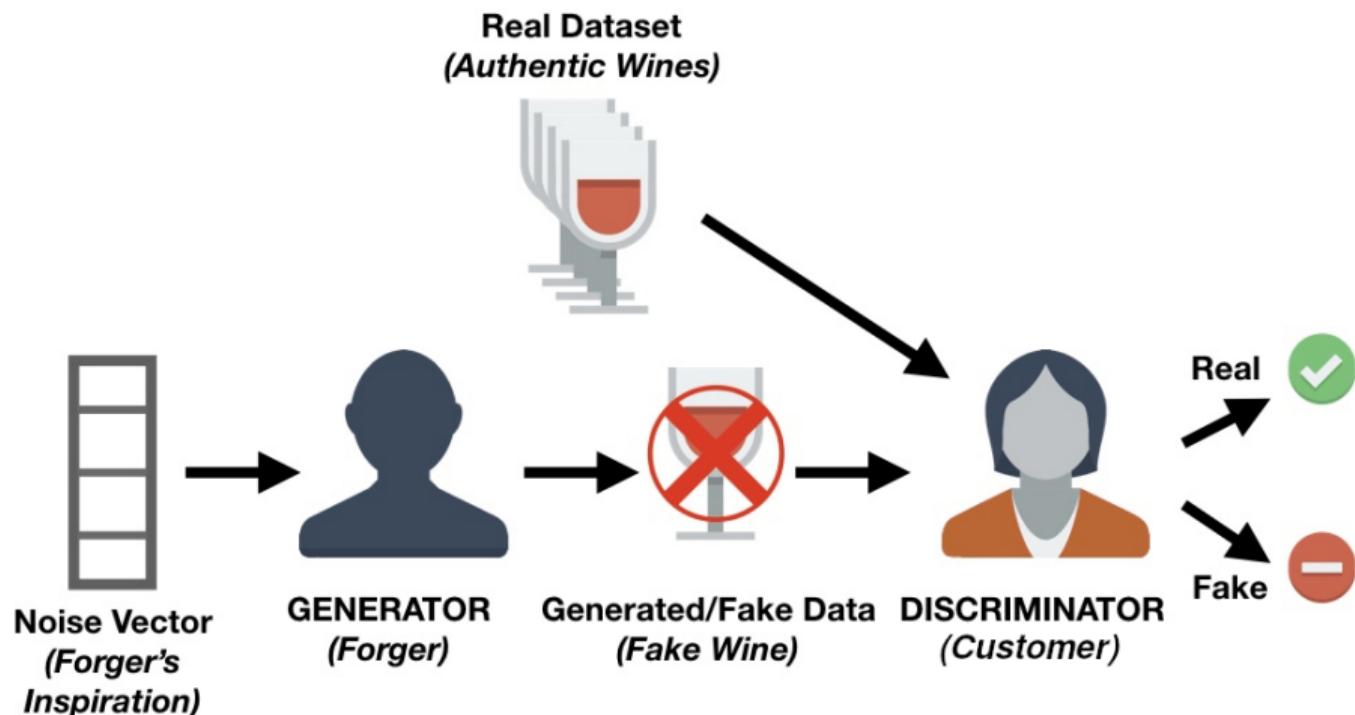
Proto-GAN example I



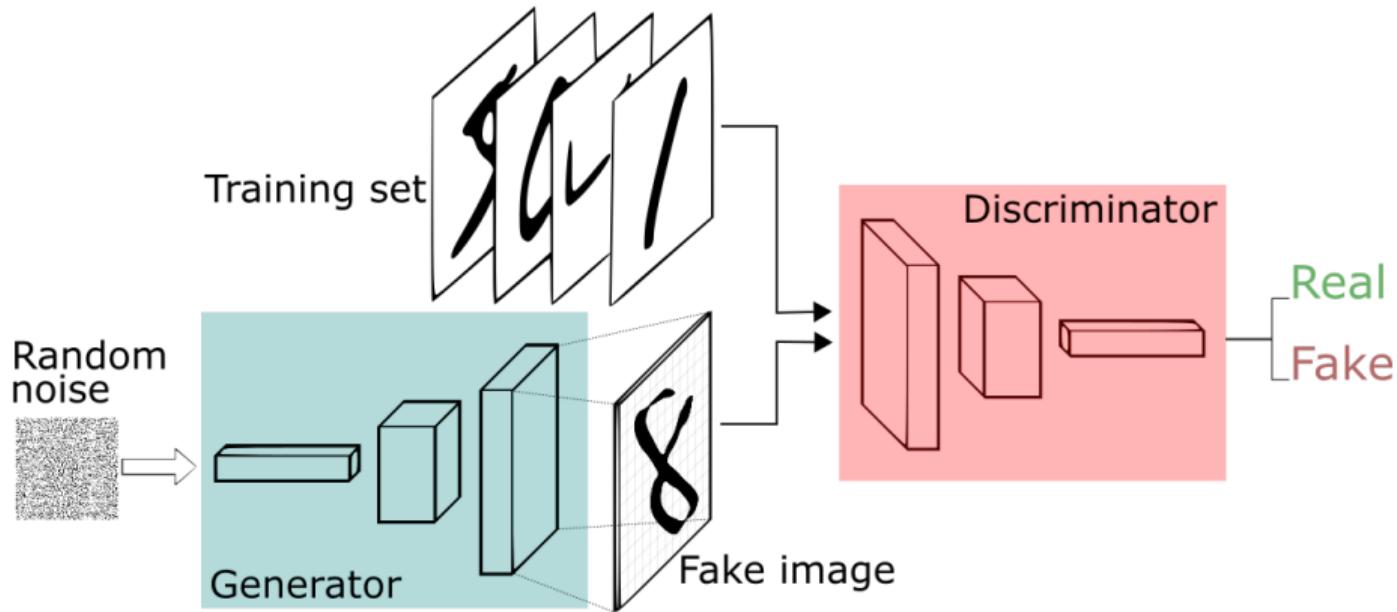
Proto-GAN example II



Proto-GAN example III



GAN model I



GAN model II

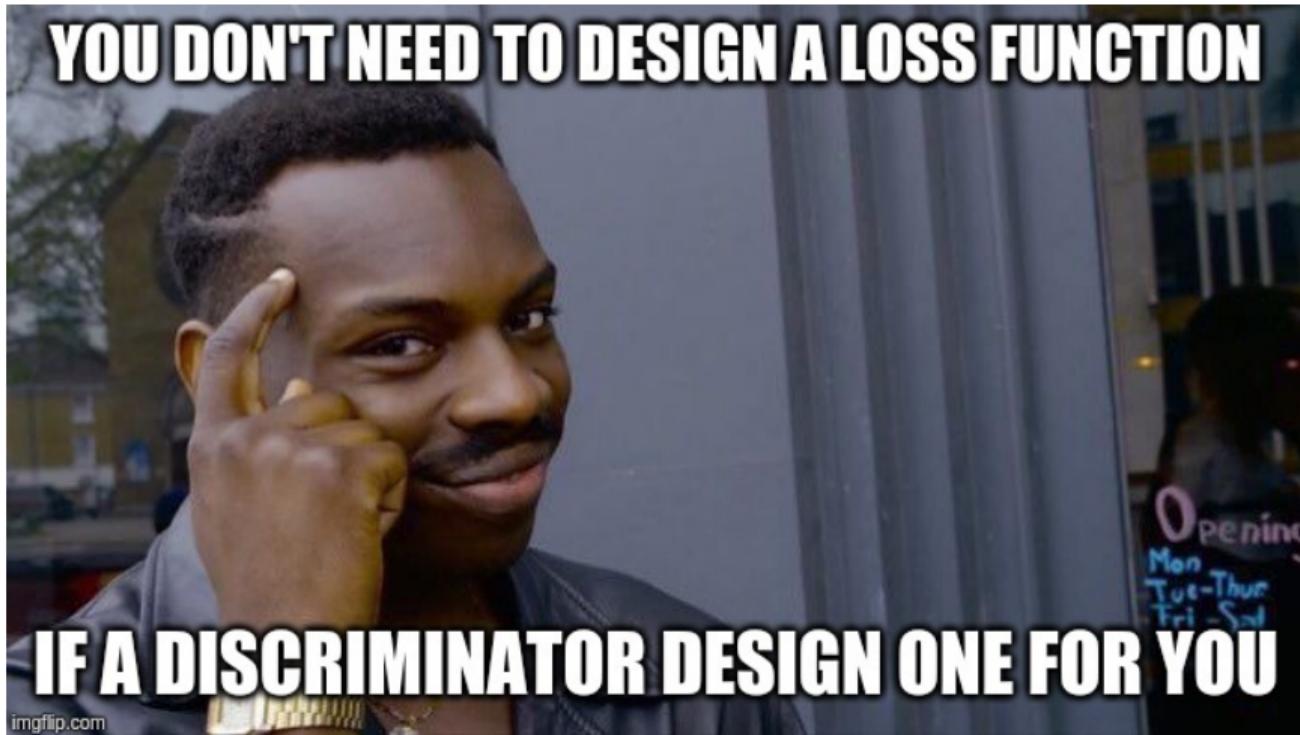
Generator

- Takes as input a noise vector, and output a sample as similar as possible to real data.
- Unsupervised learning.
- (Implicit) Generative model.

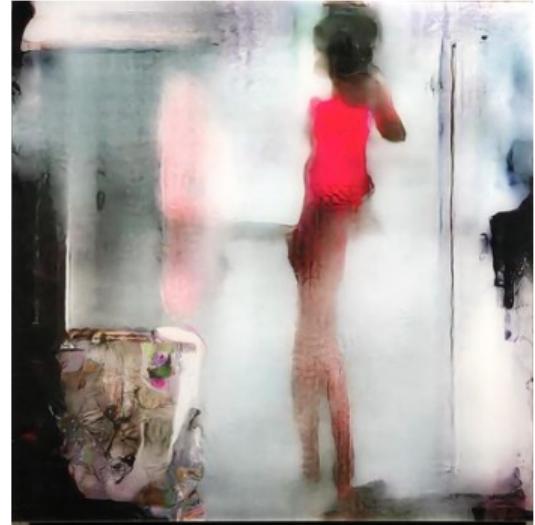
Discriminator

- Takes as input real and fake data, and tries to discriminate between them.
- Supervised learning.
- Discriminative model.

Why GANs are everywhere?



Some examples



¹⁶Images from Wikipedia (Edmond de Belamy), Mario Klingemann (see also here)

Image-to-image translation |

- Like a language translation, we want to translate one image from one domain to another, maintaining unchanged the semantic content.
- The ground truth result of the translation is not known, and more than one result might be correct.

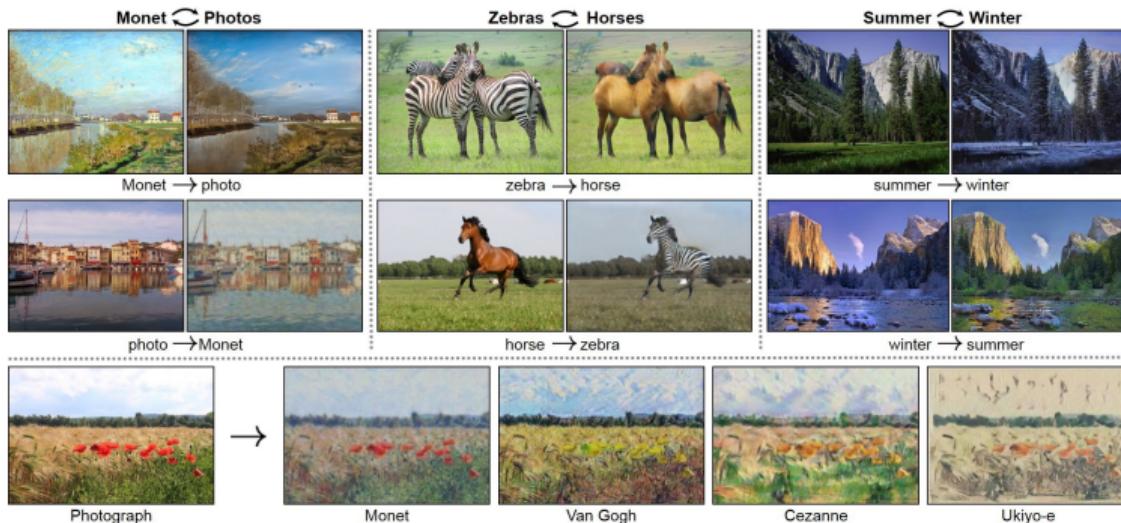
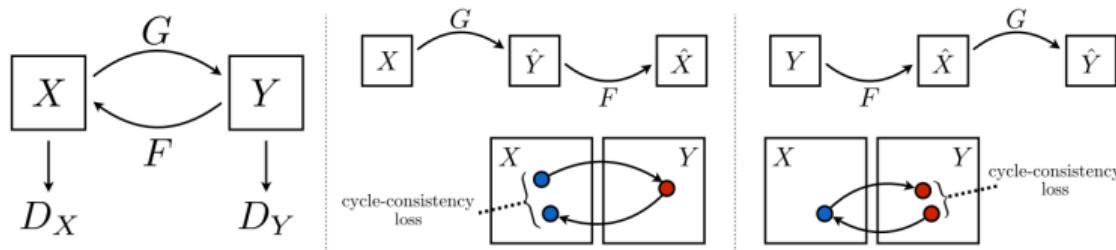


Image-to-image translation II

- The problem is similar to the problem of learning to translate between 2 languages without a dictionary.
- We could exploit the *cycle consistency* properties of mappings:

$$F(G(x)) \approx x \quad \text{and} \quad G(F(y)) \approx y$$

- We force the model to learn the *inverse mapping*, and the composition of the 2 translation have to be similar to the input.



Some examples

- Resurrecting Ancient Cities by Jack Clark.
- Portrait to Dollface by Mario Klingemann.
- Monet paintings to photographs (we now can see what Monet saw).
- Image Animation by Aliaksandr Siarohin *et al.*
- Many more, and there is space for your ideas!

Art and creativity

- GANs are really good at imitating real data, so they can produce piece of art that resemble real art produced by humans.
- As an example, they can imitate pretty well the style of a painter, or the genre of music of a track.
- This is creativity or imitation?



Creative Adversarial Networks (CANs)

- We want the generator to be creative:

“The use of imagination or original ideas to create something.”

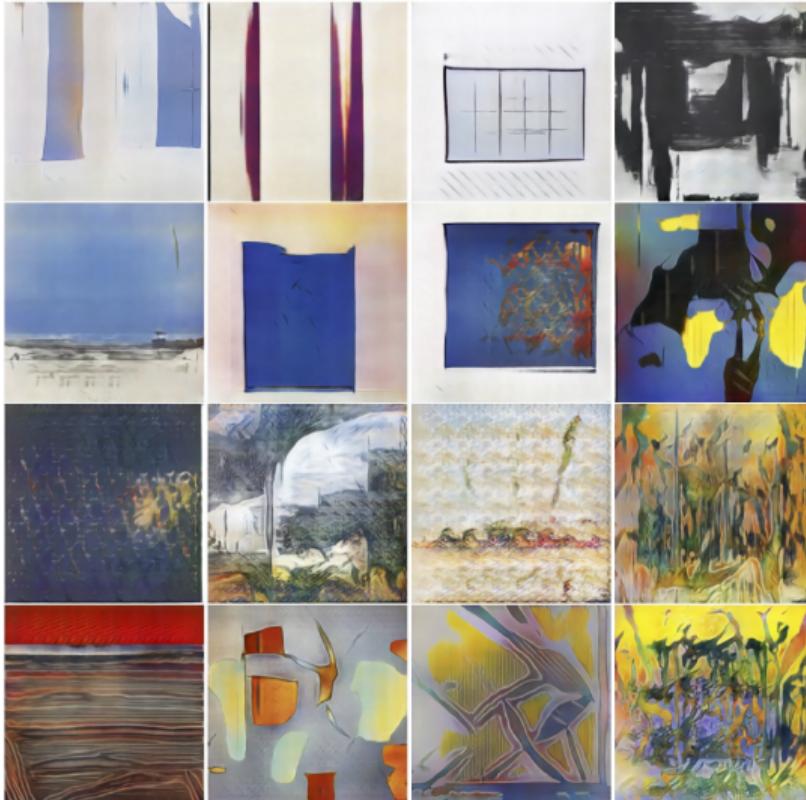
Oxford dictionary

- The discriminator discriminate between real and generated art.
- To include creativity in the process, the discriminator also classify artworks into a style (cubism, impressionism, . . .).
- If a generated image is classified as art but the discriminator is not able to classify it in a known style, the generated image can be considered a new and creative work.

Creative Adversarial Networks (CANs)



Creative Adversarial Networks (CANs)



Creative Adversarial Networks (CANs)

Painting set	Q1 (std) Intentionality	Q2 (std) Visual Structure	Q3 (std) Communication	Q4 (std) Inspiration
CAN	3.3 (0.47)	3.2 (0.47)	2.7 (0.46)	2.5 (0.41)
Abstract Expressionist	2.8 (0.43)	2.6 (0.35)	2.4 (0.41)	2.3 (0.27)
Art Basel 2016	2.5 (0.72)	2.4 (0.64)	2.1 (0.59)	1.9(0.54)
Artist sets combined	2.7 (0.6)	2.5 (0.52)	2.2 (0.54)	2.1 (0.45)

- Q1: As I interact with this painting, I start to see the artist's intentionality: it looks like it was composed very intentionally.
- Q2: As I interact with this painting, I start to see a structure emerging.
- Q3: Communication: As I interact with this painting, I feel that it is communicating with me.
- Q4: Inspiration: As I interact with this painting, I feel inspired and elevated.

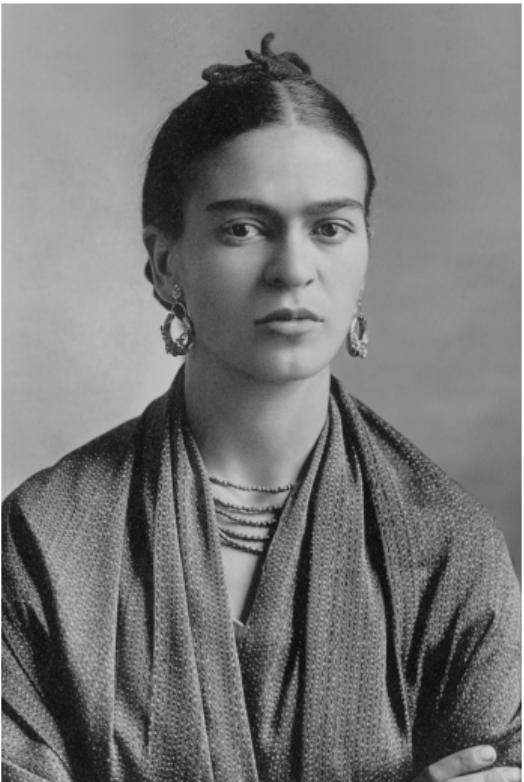
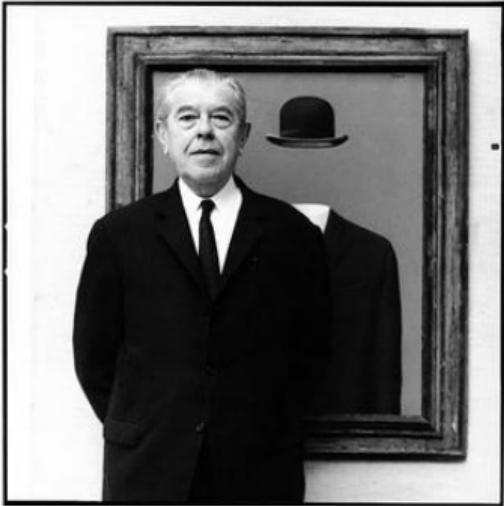
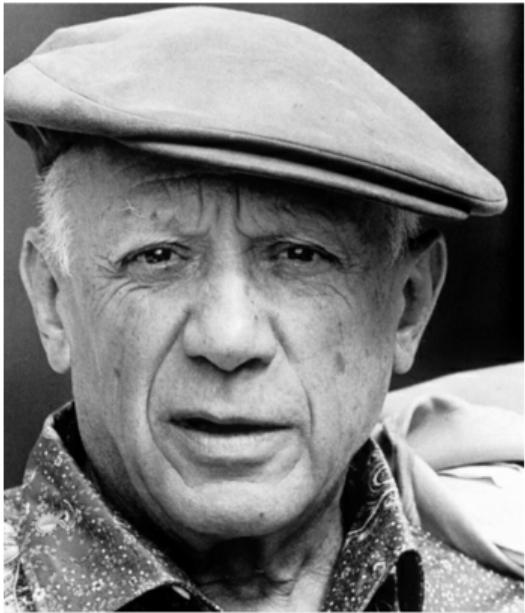
Q&A

Antennas



¹⁷ Image from Wikipedia.

Until now we have seen creativity just in the arts...



¹⁸Images from Wikipedia.

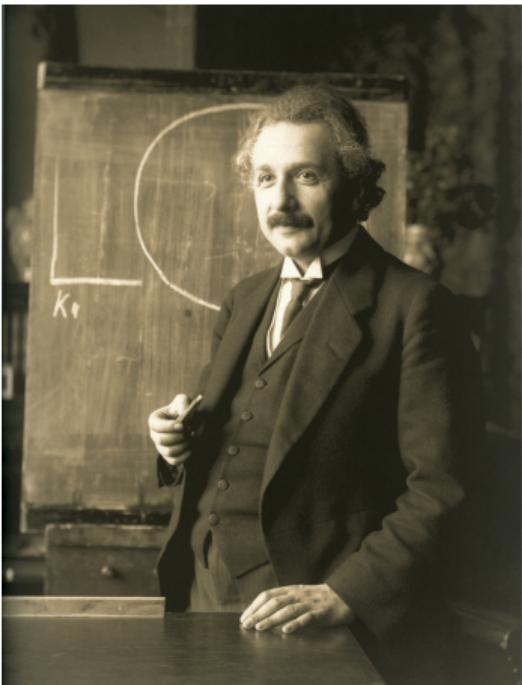
But creativity is not limited to arts...



- Think outside the box.
- Resolve unresolved problems.
- Solve solved problems in a new creative way.
- Don't be afraid to go against the common beliefs.

¹⁹Image from CNN.com

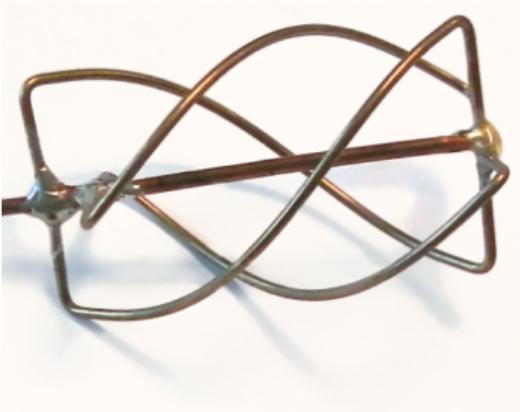
An history of creativity



- It's 1905.
- 17 years before Michelson and Morley demonstrated (by accident) that the speed of light is always constant.
- This is counter-intuitive and it was a huge problem for all the physical theories of the time.
- Einstein resolve this big problem with the (special) theory of relativity, in a very creative way...

²⁰Image from Wikipedia

Another history of creativity



- It's 2006.
- Nasa want to launch a mission called Space Technology 5 (ST5) to study the Earth's magnetosphere.
- Scientists struggled to design an effective antenna to communicate with Earth.
- Commonly used quadrifilar helix antennas did not work well.

²⁰Image from orbanmicrowave.com

The solution



²⁰Image from Wikipedia

Genetic Algorithms

- 1 Start from a random population.
- 2 Test every single individual.
- 3 Select the top $k\%$ performing individuals.
- 4 The next generation of individuals is generated combining the characteristic of 2 or more individuals (crossover).
- 5 Apply some random mutations.
- 6 Go to 2.

Why it's creative?

- We have no control on the evolution of the population. We don't know the best solution to the problem and the solution could be very different from the one we think of.
- No humans' preconceptions.
- Really creative way of doing things usually emerge from these systems (especially in locomotion).

Evolutionary Art



²¹ Image from evogenio.com

Evolutionary creativity

- There is a large class of different problems that can be solved with evolutionary creativity.
- Evolutionary system can also be used to produce pieces of art like paintings, music, poetry...
- The field is very rich and there is space for new ideas and approaches.
- If you are interested this is a must read *The Surprising Creativity of Digital Evolution: A Collection of Anecdotes from the Evolutionary Computation and Artificial Life Research Communities*, Joel Lehman et al. 2019.

One last example

- As said before, creativity can be defined as the ability to solve new problems or the ability to solve problems in a new and unexpected manner.
- In 2013 researchers teach computer to play Atari and NES games, often surpassing human performance.
- One interesting (and creative) behavior was learned by the agent that played Tetris.
- In Tetris there is no winning state, blocks are piled until you lose the game.
- An agent learned a very clever, creative and pretty creepy behavior. Since the game cannot be won, the only to not to lose is not to play.
- The agent played quite randomly, and paused the game forever before losing the game.
- <https://www.youtube.com/watch?v=-cKeGk3R3qE>

One last example

- A similar behavior was learned by AlphaGo, the computer program developed by Google's DeepMind to defeat humans at the game of go.
- In 2016 the program won against Lee Sedol, at the time considered one of the best players at go.
- The most interesting thing about AlphaGo is that many moves, that later will prove successful, at first seem strange and without sense.
- The style of play of AlphaGo was not similar to the one played by humans.

The algorithm seems to be holding back its power. Sometimes it plays moves that lose material because it is seeking simply to maximise its probability of reaching winning positions, rather than — as human players tend to do — maximise territorial gains.

The Go Files: AI computer clinches victory against Go champion, Tanguy Chouard, Nature 2016

Conclusions

- Creativity is not a well defined concept and it is not known if it can be taught to humans or machines.
- Computers can be used as a tool for creating new kinds of art, music etc.
- Collaboration between human and computer is very tight. Artificial intelligence can open new ways and types of creativity.
- Usually AI, when it is not conditioned by humans or social priors, exhibit a non-human and surprising behavior in resolving problems. This *think-out-of-the-box* behavior would be considered creative if it were shown by a human.
- Creative AI has shown impressive results in solving problems, playing games, designing things and evolving behavior.

Conclusions

- The field is still in its infancy, and there is a lot of space for exploring new ideas and new directions.
- Usually the best results are the ones made by artists and scientists working together.
- In my opinion one of the most promising directions is evolutionary creativity.

But:

- The same technology that we have seen today can be used for malicious actions, such as producing deepfakes, fake news, etc.
- There is also an ethical dilemma in using these creative technologies, e.g. for writing news articles. What if the model is biased? What if the model is not fair?
 - ▶ More on this on the tomorrow's morning talk by [Marta Ziosi](#).

If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea.

Antoine de Saint-Exupery

Thank you!



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- Like us on social media (Linkedin, Facebook, Twitter).
- Talk about us (share a post about the workshop, share our initiatives).
- Participate in our projects and in our monthly meetups.
- Offer us a coffee (or a tea in my case) [here](#).

Q&A

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