Deep Generative Models Introduction

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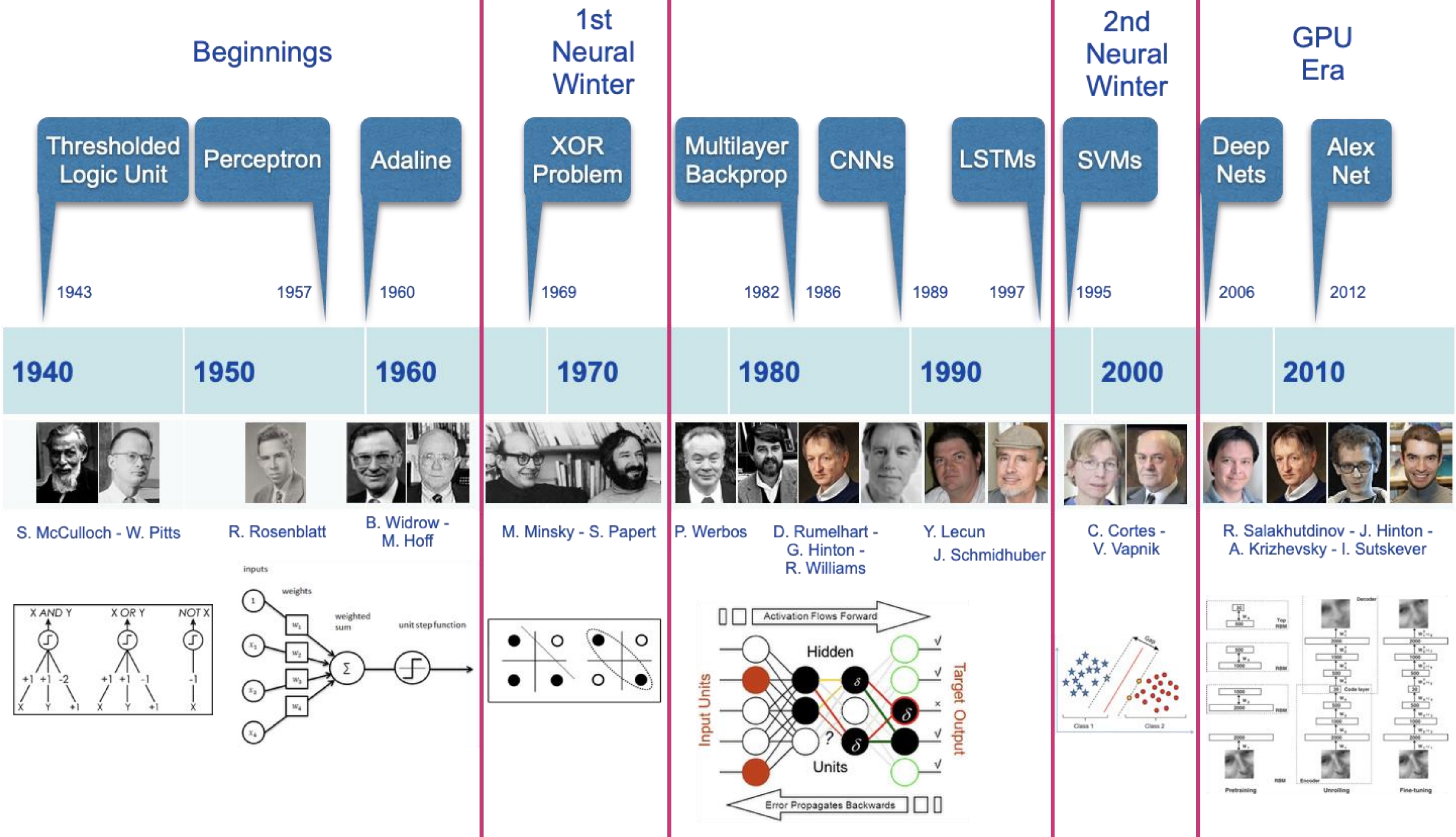

Beginnings
1st Neural Winter
2nd Neural Winter
GPU Era
Thresholded Logic Unit
1943
Perceptron
1957
Adaline
1960
XOR Problem
1969
Multilayer Backprop
1982
1986
CNNs
1989
LSTMs
1997
SVMs
1995
Deep Nets
2006
Alex Net
2012
1940
1950
1960
1970
1980
1990
2000
2010
S. McCulloch - W. Pitts
R. Rosenblatt
B. Widrow - M. Hoff
M. Minsky - S. Papert
P. Werbos
D. Rumelhart - G. Hinton - R. Williams
Y. Lecun
J. Schmidhuber
C. Cortes - V. Vapnik
R. Salakhutdinov - J. Hinton - A. Krizhevsky - I. Sutskever
X AND Y
X OR Y
NOT X
inputs
weights
weighted sum
unit step function
Activation Flows Forward
Hidden
Units
Input Units
Target Output
Error Propagates Backwards
Class 1
Class 2
Pretraining
Unrolling
Fine-tuning

Generative AI timeline

General model research · Image / video models · Text models · Business events

December 1997
Two computer scientists, Sepp Hochreiter and Jürgen Schmidhuber, invent Long Short-Term Memory (LSTM) networks, which improves memory capacity in neural networks and thus allows for faster and more precise pattern recognition in training data.[6]

2012
A seminal year in deep learning research that enables significant advances in computer vision, speech recognition, and natural language processing.[5] These accomplishments are best signified by AlexNet, a convolutional neural network (CNN) trained on graphical processing units (GPUs) and developed by researcher Alex Krizhevksy. AlexNet was the first model to break 75% accuracy, identifying images from a 14-million-image manually tagged database known as ImageNet.

December 2013
Diederik P. Kingma and Max Welling publish a paper on VAEs.[6] VAEs deconstruct input data into code, known as the latent space, and then construct new, representative data out of the latent space.

January 2014
Google acquires DeepMind, an AI research lab based in the UK.

June 2014
Ian Goodfellow invents GANs.[6]

March 2015
Researchers Jascha Sohl-Dickstein, Eric A. Weiss, Niru Maheswaranathan, and Surya Ganguli introduce diffusion models.[6] These models apply noise to an image until it is incomprehensible, then gradually reduce the noise in the image and thus learn how to generate actual images from noise.

July 2015
Google's DeepDream model for image generation is launched.[7]

December 2015
OpenAI is founded as a non-profit, open-source research lab.

June 2016
Style Transfer, a deep neural network that can transfer the style of one image to another, is released.[7]

June 2017
Google researchers release "Attention Is All You Need" paper on transformer models, a type of neural network architecture that lends attention to context and syntax.[8] This allows for immense strides in natural language processing and understanding.

1997 · 2012 · 2013 · 2014 · 2015 · 2016 · 2017

5: "2012: A Breakthrough Year for Deep Learning," Medium, Bryan House, July 17, 2019.
6: "The Generative AI Revolution Has Begun—How Did We Get Here?," Ars Technica, Haomiao Huang, January 30, 2023.
7: "Timeline of Text-To-Image Machine Learning Models," Fabian Mosele, n.d., accessed March 9, 2023.
8: "Timeline of AI and Language Models," Life Architect, Alan D. Thompson, n.d., accessed March 9, 2023.

GENERATIVE AI TIMELINE

General model research · *Image / video models* · *Text models* · *Business events*

2018

June 2018
OpenAI releases GPT (Generative Pre-Trained Transformer), ushering in a new era of large language models.

November 2018
Google releases its Bidirectional Encoder Representations for Transformers (BERT).

December 2018
NVIDIA's StyleGAN is able to generate hyper-realistic faces.

December 2018
Google and DeepMind's AlphaFold, a protein structure prediction model, places first in the Critical Assessment of Protein Structure (CASP) competition.

2019

February 2019
GPT-2 is released.

March 2019
OpenAI announces that it has moved from a nonprofit to "capped-profit" business model in order to attract more investors.[9]

March 2019
Chinese company Baidu releases its answer to Google's BERT: Enhanced Representation Through Knowledge Integration (ERNIE 1.0).

July 2019
Microsoft invests $1 billion into OpenAI and signs an exclusive partnership with the research startup.

July 2019
Baidu releases ERNIE 2.0, which outperforms Google's BERT.

October 2019
Google applies its BERT model to searches—demonstrating semantic search capabilities.

2020

May 2020
GPT-3 is released with 175 billion parameters, 100 times that of GPT-2.

September 2020
GPT-3 writes a newspaper column in The Guardian.

November 2020
AlphaFold wins the CASP competition by a large margin and is recognized by organizers as a solution to the "protein-folding problem."[10]

9: "OpenAI Shifts From Nonprofit to 'Capped-Profit' to Attract Capital," TechCrunch, Devin Coldewey, March 11, 2019.
10: "DeepMind's Protein-Folding AI Has Solved a 50-year-old Grand Challenge of Biology," MIT Technology Review, Will Douglas Heaven, November 30, 2020.

GENERATIVE AI TIMELINE

General model research · *Image / video models* · *Text models* · *Business events*

2021

January 2021
OpenAI launches Dall-E, its text-to-image model, along with the open-source version of the model: Contrastive Language-Image Pre-Training (CLIP). This enables a flood of text-to-image models.

May 2021
Google announces Language Model for Dialogue Applications (LaMDA), its transformer-based large language model.

June 2021
GitHub, a subsidiary of Microsoft, announces its code-completion Copilot tool. GitHub Copilot is built on OpenAI's Codex, which is trained on 54 million public GitHub repositories.

November 2021
Microsoft announces NÜWA, a multimodal model for text-to-image and text-to-video.

December 2021
Baidu releases ERNIE 3.0.

2022

March 2022
MidJourney, a text-to-image model offered through a Discord server, moves into open beta.

April 2022
Google releases its 540 billion parameter Pathways Language Model (PaLM), a multifunctional language model.

April 2022
OpenAI releases Dall-E 2. Shortly thereafter, Boris Dayma releases an open-source but unaffiliated version called Dall-E Mini. Dayma's model eventually changes its name to Craiyon to avoid any legal disputes. Craiyon becomes rapidly popular due to its accessibility and through memes.

May 2022
Meta releases its Open Pretrained Transformer (OPT) model, a totally open-source LLM, to the public. Details about the model's training are also released. Access is available upon request, but the license limits usage of the model to research purposes.

May 2022
Google releases its answer to Dall-E, Imagen, though not to the public.

July 2022
Research startup Stability.ai launches Stable Diffusion, an open-source text-to-image model.

July 2022
The French National Center for Scientific Research debuts BigScience Large Open-Science Open-Access Multilingual Language Model (BLOOM) on the platform HuggingFace. With 176 billion parameters, BLOOM is larger than GPT-3 and also completely open-source. It goes beyond Meta's OPT by being freely available for research or commercial use.

September 2022
NVIDIA releases Get3D, a 3D-shape generator trained only on 2D images.

September 2022
Meta announces Make-A-Video, its text-to-video model.

GENERATIVE AI TIMELINE

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October 2022
Google launches text-to-video model Imagen Video.

November 2022
OpenAI announces ChatGPT, a powerful chatbot tool running on the GPT-3.5 model. It soon becomes the most quickly adopted tech product in history.

November 2022
Stability.ai and Amazon Web Services announce a partnership.

2023

January 2023
Microsoft announces a "multiyear, multibillion-dollar" investment in OpenAI and exclusive integration with its Azure cloud system.[11]

February 2023
AWS and Hugging Face announce partnership.

February 2023
Runway, an AI research lab, announces its Gen-1 model that allows for style transfer across videos.

February 2023
Microsoft releases a limited beta upgrade to its Bing search system, with new capabilities such as summarization and chat based on ChatGPT. GPT is also integrated into other Microsoft products including Teams and its Edge browser.

February 2023
Google invests $300 million into Anthropic, a research startup made up of former OpenAI employees. Anthropic calls Google its "preferred cloud provider."[12]

February 2023
Google announces BARD, its answer to ChatGPT, for limited beta testing.

March 2023
Google announces generative tools to be integrated into workplace.

March 2023
OpenAI releases GPT-4.

11: "Microsoft Announces New Multibillion-Dollar Investment in ChatGPT-Maker OpenAI," CNBC, Ashley Capoot, January 23, 2023.
12: "Google Invested $300 Million in AI Firm Founded by Former OpenAI Researchers," The Verge, James Vincent, February 3, 2023.

ASSISTANT Produce a diagram with the history of generative models for images from 1950 to 2000

ASSISTANT As an AI, I can't directly produce images or diagrams. However, I can describe how such a timeline could look:

1. 1950s to Early 90s - Basic Algorithms: In the early era of computing, image synthesis was rather basic and primitive. There weren't any sophisticated models or algorithms that could generate images. Methods used were elementary like connected components for binary image, histogram modelling, etc.

2. Mid 90s - Fractal Geometry: Fractal geometry was then used to generate images particularly terrain and natural-looking structures.

3. Late 90s - Texture Synthesis Methods: Towards the end of the 90s, methods for texture synthesis were developed which used pixel-based and patch-based copying algorithms. Some examples of these techniques include Image Quilting and Efros Leung.

4. 2000s onwards - Development of Generative Models: With the turn of the century, more direct models for generating images were produced. This includes algorithms such as Generative Adversarial Networks(GANs).

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Give us feedback

USER What about stochastic grammars for images?

ASSISTANT Indeed, stochastic grammars have been used as generative models for images as well. Stochastic image grammars are a particularly expressive class of generative models that have proven useful in a wide range of applications, from texture synthesis to object detection in computer vision.

To add this to the timeline:

1980s-2000s - Stochastic Grammars: In the 80s and into the 2000s, stochastic grammars, such as Stochastic Context-Free Grammars (SCFGs), began to be used to generate complex structured images. These models, inspired by Chomsky's work on formal grammars in linguistics, provide a structured, hierarchical way to model the relationships between different parts of an image.

Remember to consult a graphic designer to create a visual timeline and to research more detailed information as required. Also note that many of these technologies developed in parallel and continuously improved over time.

Stochastic Grammars

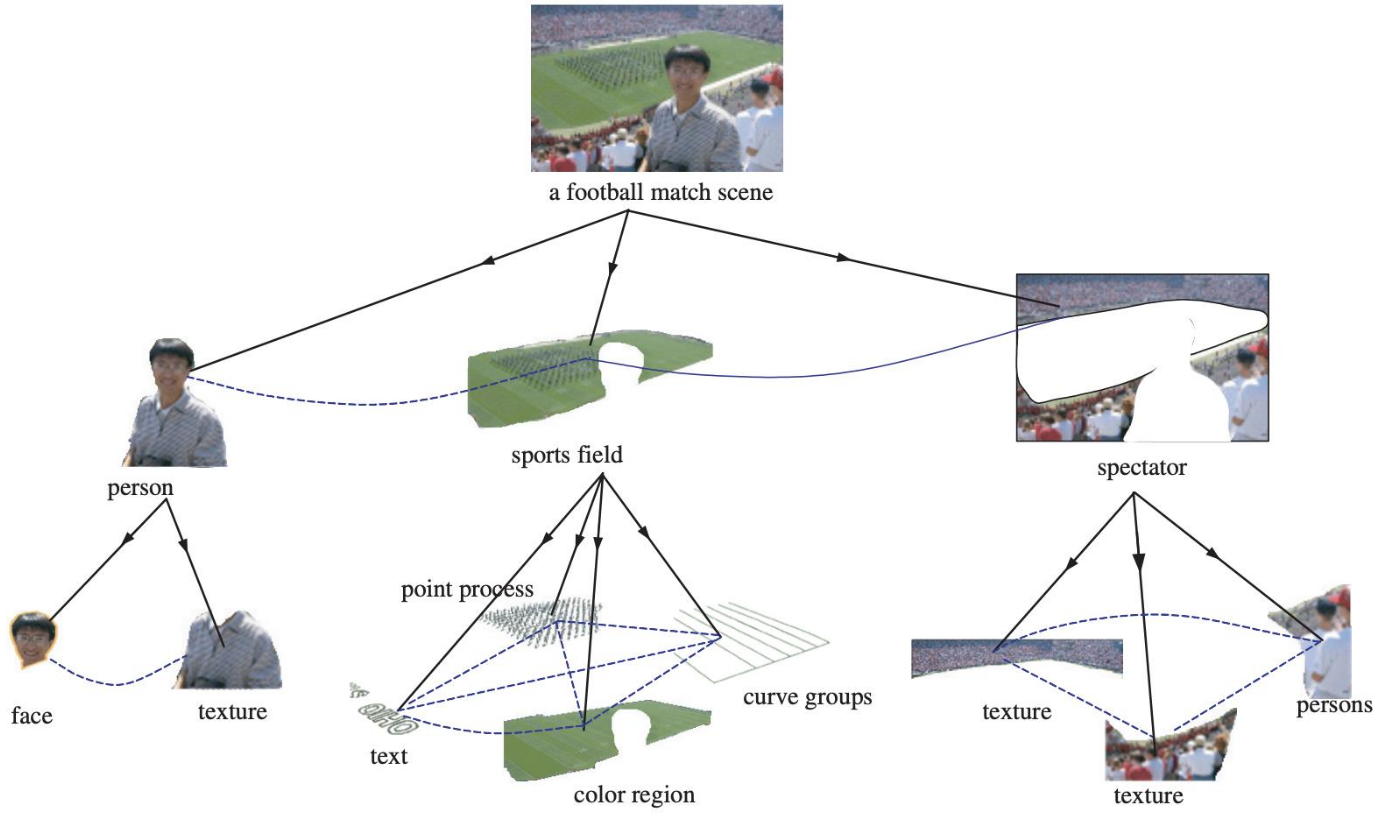

Fig. 1.1 Illustrating the task of image parsing. The parse graph includes a tree structured decomposition in vertical arrows and a number of spatial and functional relations in horizontal arrows. From [72].

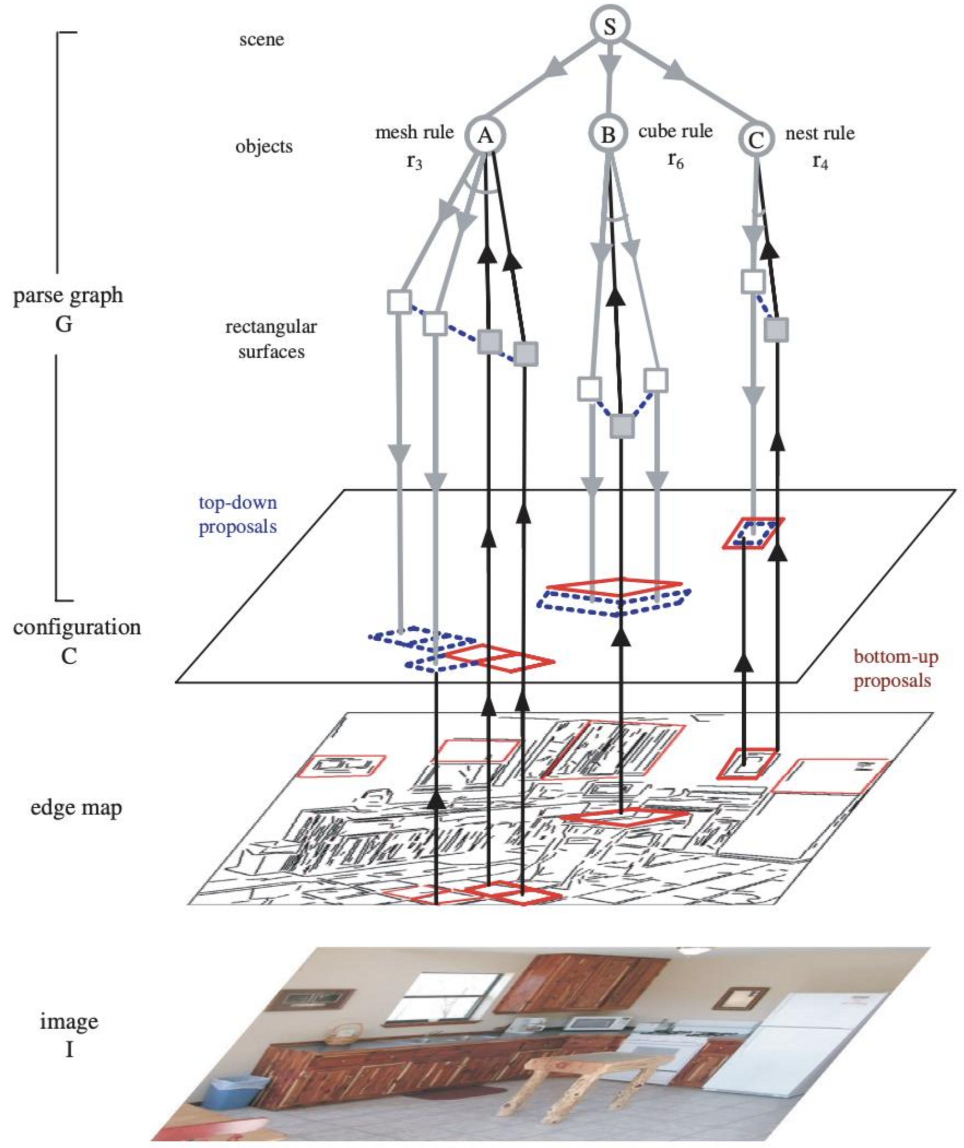

Fig. 1.2 Illustrating the recursive bottom-up/top-down computation processes in image parsing. The detection of rectangles (in red) instantiates some non-terminal nodes shown as upward arrows. They in turn activate graph grammar rules for grouping larger structures in nodes A, B, and C, respectively. These rules generate top-down prediction of rectangles (in blue). The predictions are validated from the image under the Bayesian posterior probability. Modified from [59].

ASSISTANT

Probabilistic generative models were largely developed in the 20th century, with many key concepts emerging in the latter half of the century.

Here is a rough timeline:

1. 1950s: In the mid-20th century, simple statistical models like Markov models were being used, which can be considered as early instances of generative models.

2. 1980s-1990s: During this era, probabilistic generative models became more sophisticated. Bayesian networks and hidden Markov models (HMMs) were popular methods around this time.

3. 1990s-2000s: Mixture models, like Gaussian Mixture Models (GMMs), and other latent variable models were developed during the 90s and into the 2000s, becoming a powerful tool for analyzing and generating data.

4. 2000s-Present: More recently, this category has grown to include models like Deep Boltzmann Machines and Generative Adversarial Networks (GANs), which are very powerful and intricate generative models capable of producing highly realistic results.

Remember, this is a general overview and specific developments may have occurred at different times. Technological development is often gradual and iterative, with many different contributors adding

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Give us feedback

Topic Modeling

what about topic modeling

Topic modeling is a significant area of generative models, particularly in text analysis and natural language processing. It was developed and popularized in the late 1990s and early 2000s. Here's how it fits into the history of generative models:

Topic Modeling Timeline (1950-2000)

1980s: Early Foundations

- **1980s: Latent Semantic Analysis (LSA).** Although not strictly generative, LSA provides a foundation for topic modeling by analyzing the relationships between a set of documents and terms, reducing dimensions to uncover latent structures in the data.

1990s: Development and Formalization

- **1999: Latent Dirichlet Allocation (LDA).** Introduced by Blei, Ng, and Jordan, LDA is a probabilistic model that represents documents as mixtures of topics, and topics as mixtures of words. This approach became a cornerstone of topic modeling and generative text models

2000s: Expansion and Application

- **2003: Topic Modeling with LDA.** The LDA model gains traction in various applications, from document classification to information retrieval, influencing subsequent research and tools.

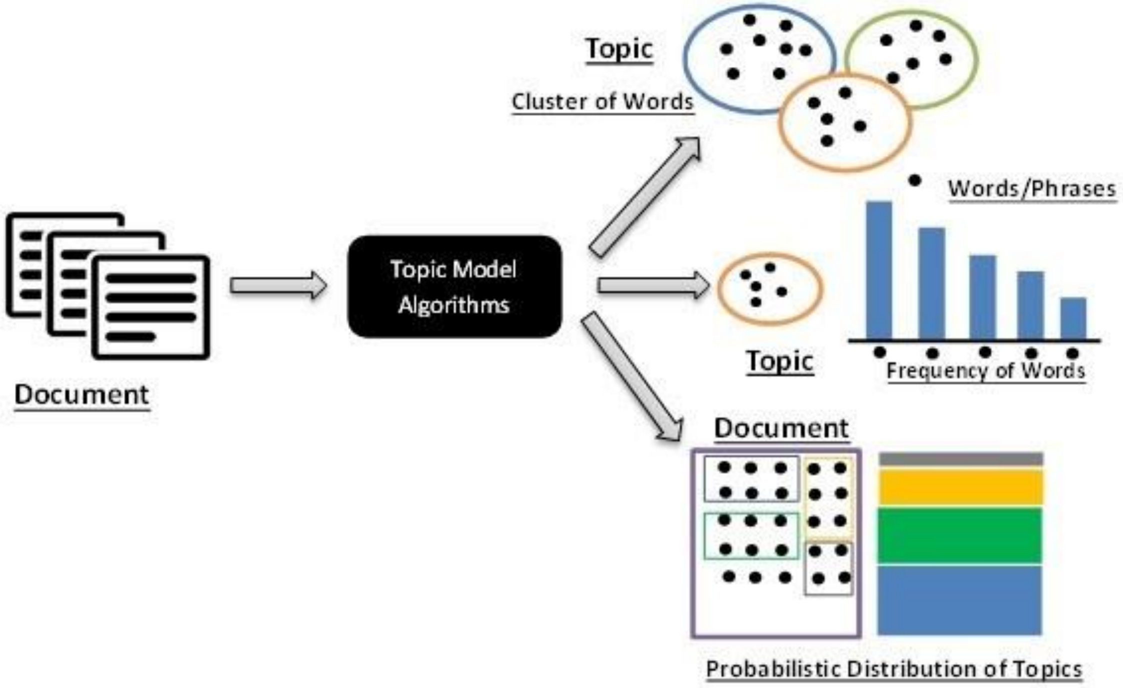


Figure-1

Progress in Generative Models of Images

Ian Goodfellow, 2019

Progress in Generative Models of Images

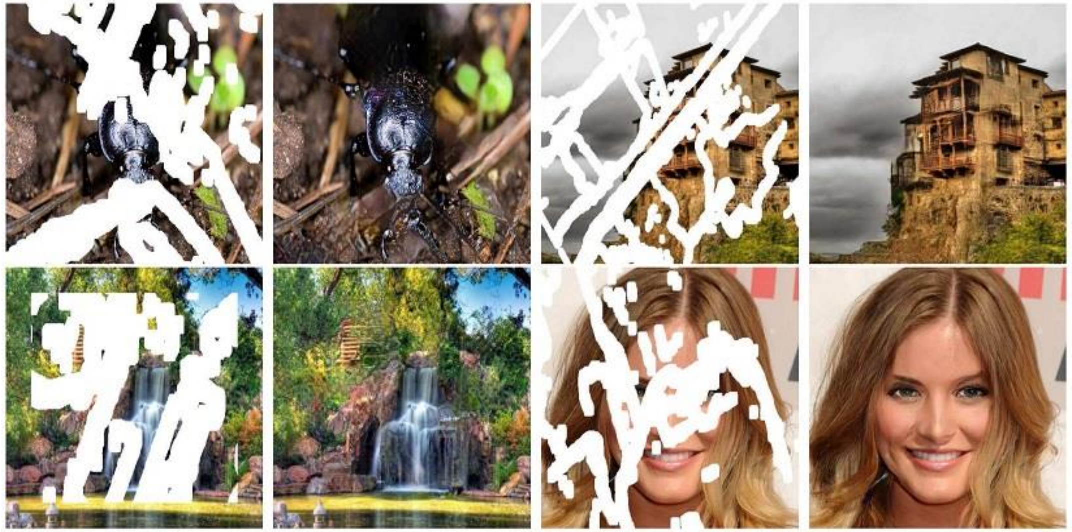

Song et al., Score-Based Generative Modeling through Stochastic Differential Equations, 2021

Progress in Inverse Problems

P(high resolution | low resolution)

Menon et al, 2020

P(full image| mask)

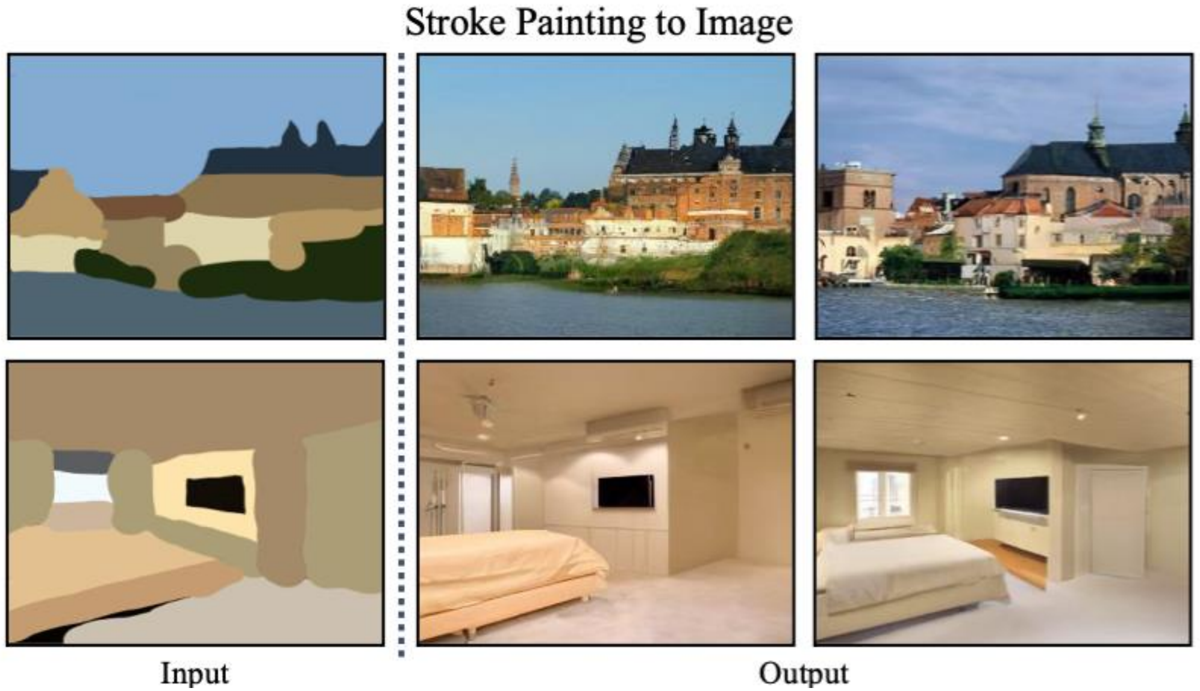


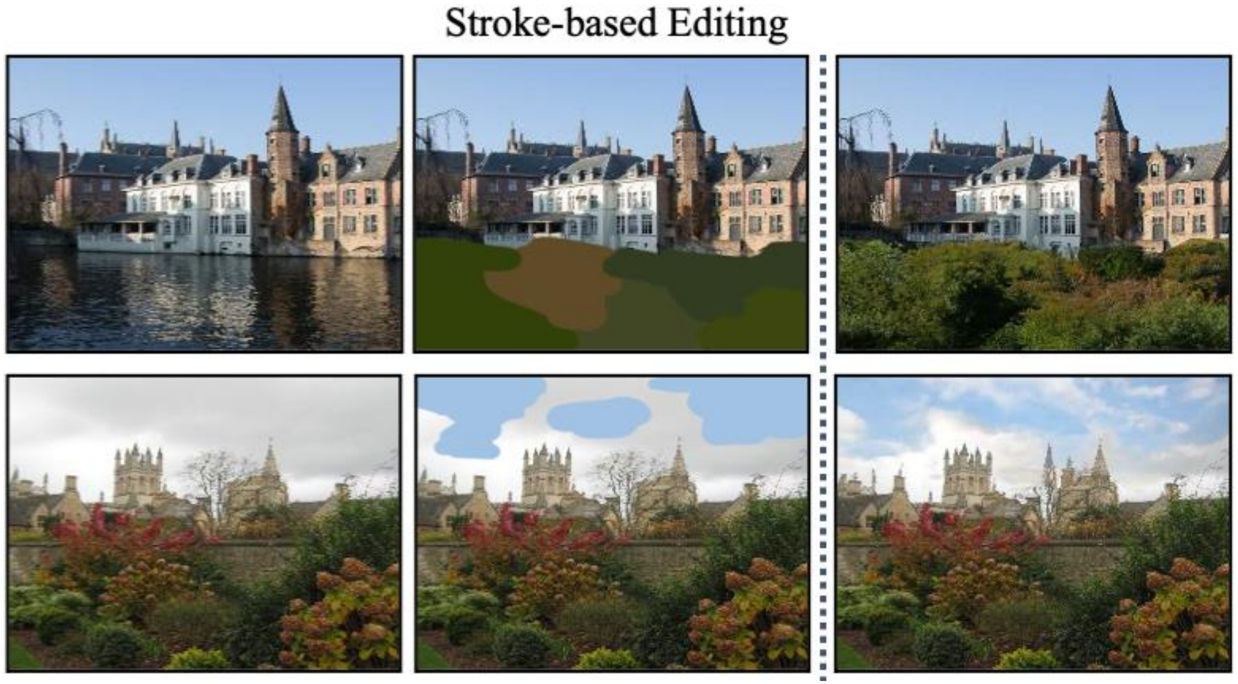
Liu al, 2018

P(color image| greyscale)

Antic, 2020

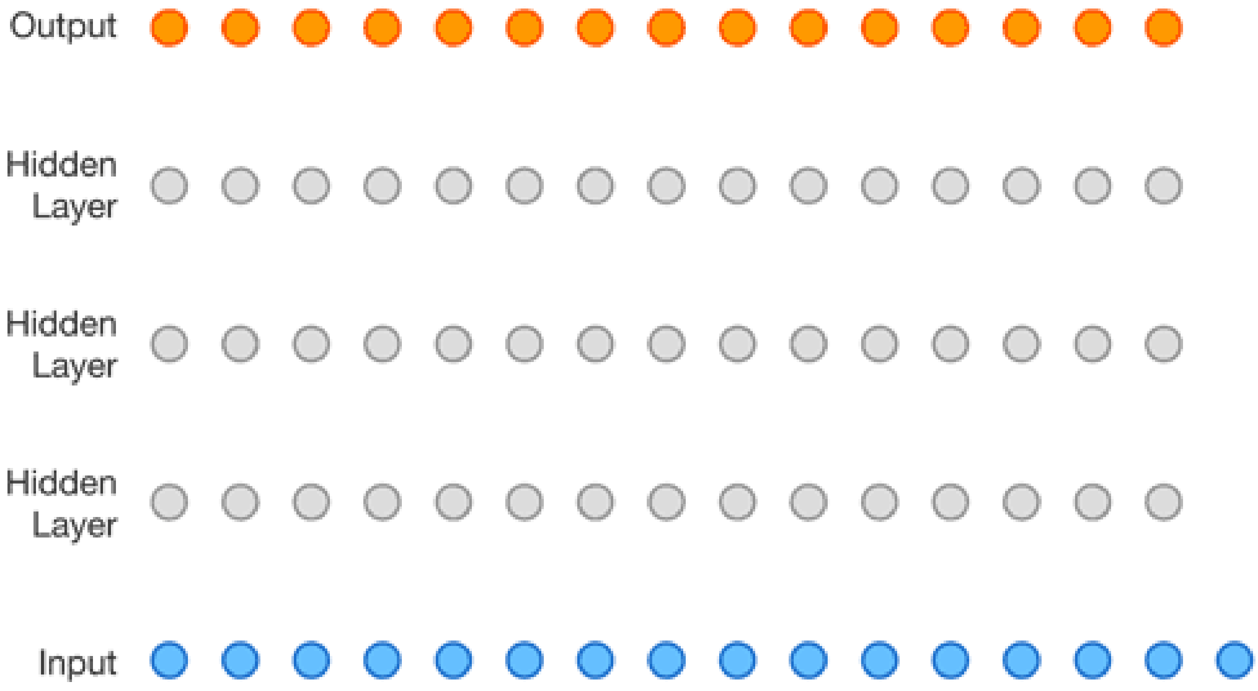
Progress in Inverse Problems





WaveNet

Generative model of speech signals



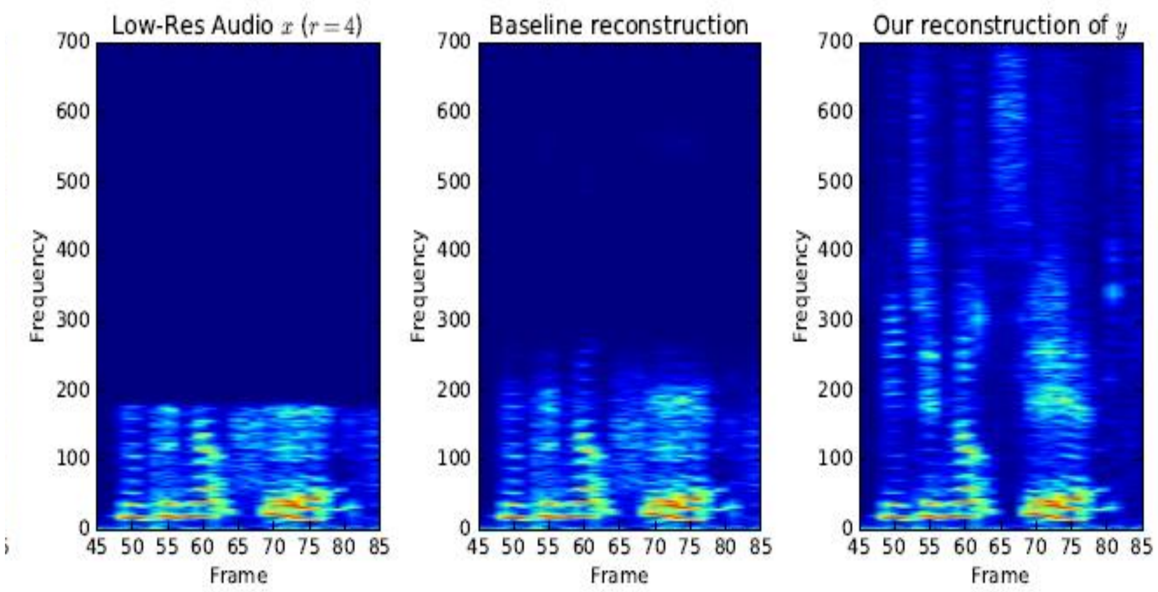
Text to Speech

- Parametric
- Concatenative
- WaveNet
- Unconditional
- Music

van den Oord et al, 2016c

Audio Super Resolution

Conditional generative model P(high-res signal | low-res audio signal)



Low res signal

High res audio signal

Kuleshov et al., 2017

Machine Translation

Conditional generative model P(English text| Chinese text)

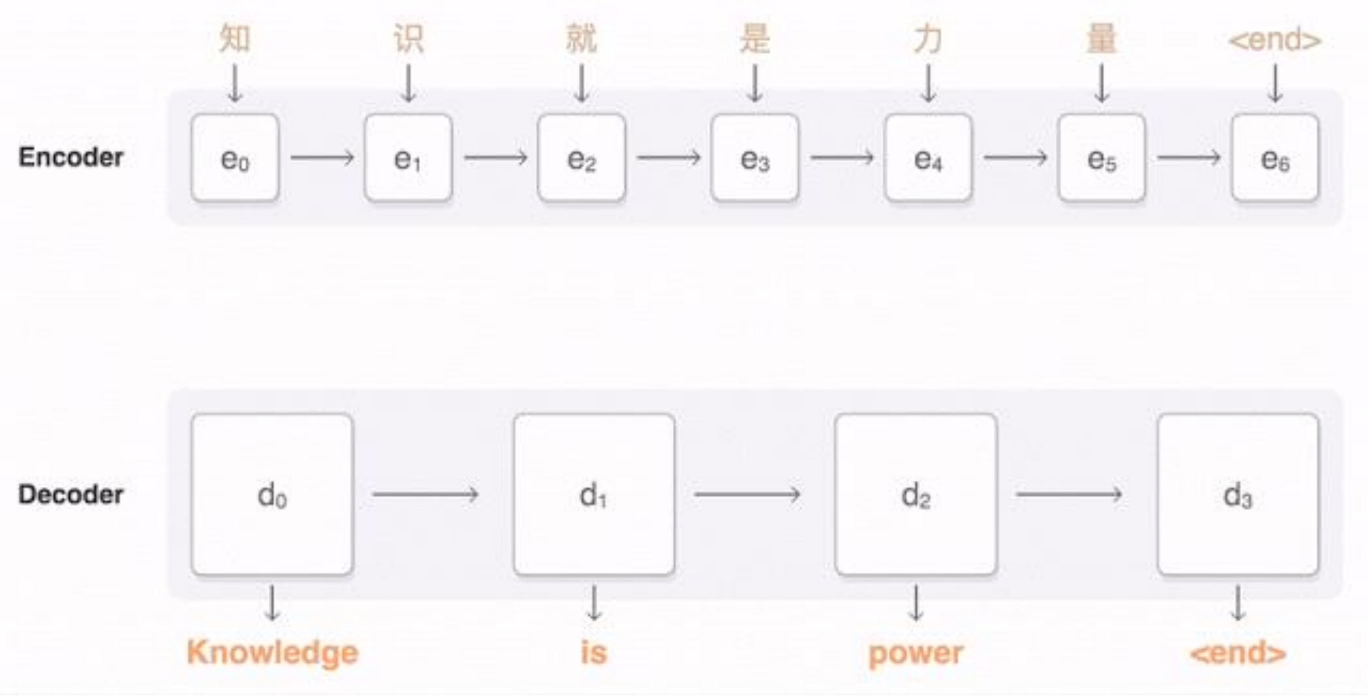


Figure from Google AI research blog.

Language Generation

Custom prompt

To get an A+ in deep generative models, students have to

Completion

To get an A+ in deep generative models, students have to be willing to work with problems that are a whole lot more interesting than, say, the ones that most students work on in class. If you're a great student, the question above can be avoided and you'll be able to do great work, but if you're not, you will need to go beyond the basics before getting good.

Now to be clear, this advice is not just for the deep-learning crowd; it is good advice for any student who is taking his or her first course in machine learning.

The key point is that if you have a deep, deep brain of a computer scientist, that's just as important to you.

P(next word | previous words)

Radford et al., 2019
Demo from talktotransformer.com

Code Generation

parse_expenses.py write_sql.go sentiment.ts addresses.rb

```python
import datetime

def parse_expenses(expenses_string):
    """Parse the list of expenses and return the list of triples (date, va
```

OpenAI Codex

Images and Text

TEXT PROMPT an armchair in the shape of an avocado. . . .

AI-GENERATED IMAGES

Edit prompt or view more images↓

P(image | caption)

TEXT PROMPT a store front that has the word ‘openai’ written on it. . . .

AI-GENERATED IMAGES

DeepFakes

Which image is real?

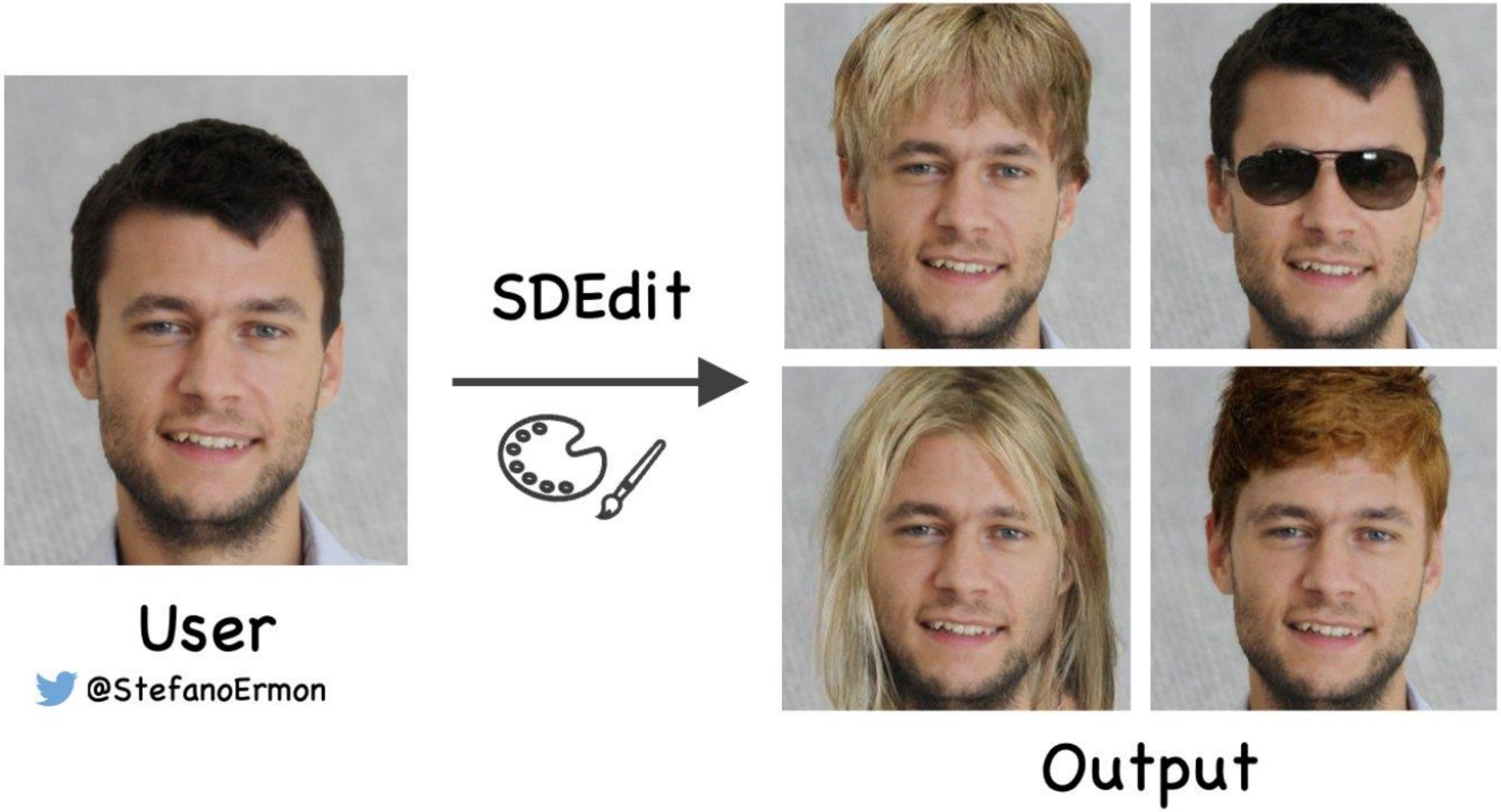


Image Translation

Conditional generative model P(zebra images| horse images)

Zhu et al., 2017