Introduction to Civil Information Systems

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Overview

Part 3

Features of Modern Computing

Key Question: How can we use modern computing technologies to improve Civil Engineering Systems?

Early Expectations of Computing

What does a computer do?

- Performs calculations – billions (sometimes even trillions) of calculations per second.
- Remembers results – gigabytes and terabytes of storage.

What kinds of calculations?

- Built-in to the language.
- User-defined by programmers.

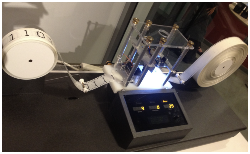
Traditional and Emerging Views of Programming:

- Computers only know what you tell them ...
- Computers discover things for themselves ...

Early Expectations of Computing

Turing Computer/Basic Primitives:

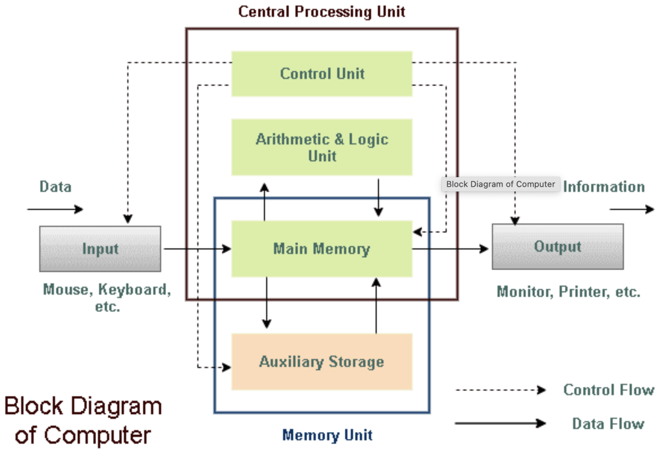
- Alan Turing (1936) created the Turing machine that included the idea of a computer program.



- He showed that you can compute anything using only 6 primitives: right, left, print, scan, erase, nothing.
- Modern programming languages have a more convenient set of primitives. Can abstract methods to create new primitives (e.g., user-defined objects).
- Anything computable in one language is computable in any other programming language.

Early Expectations of Computing

Block Diagram of a Computer:



Man and Machine (Traditional View)

Man	Machine
• Good at formulating solutions to problems. • Can work with incomplete data and information. • Creative. • Reasons logically, but very slow. • Performance is static. • Humans break the rules.	• Manipulates Os and 1s. • Very specific abilities. • Requires precise decriptions of problem solving procedures. • Dumb, but very fast. • Performance doubles every 18-24 months. • Machines will follow the rules.

Sensible Problem Solving Strategy

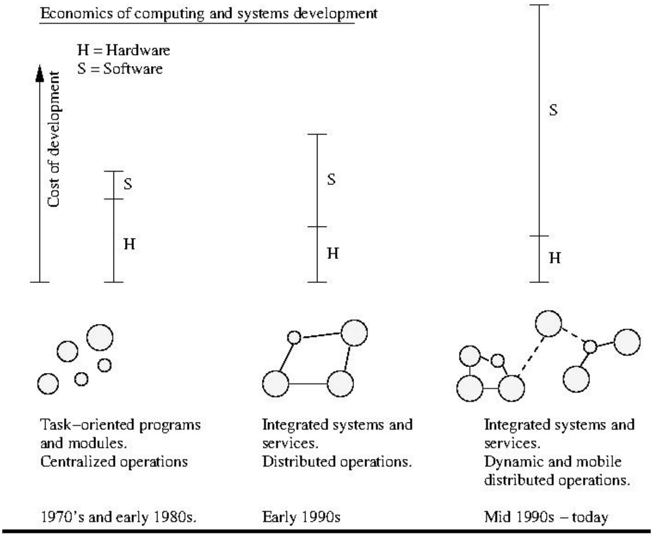
Let engineers and computers play to their strengths:

- Accelerates the solution procedure.
- Enables the analysis of problems having size and complexity beyond manual examination.
- Adds value in areas that will lead to long-term economic growth.

Getting things to work We need to:

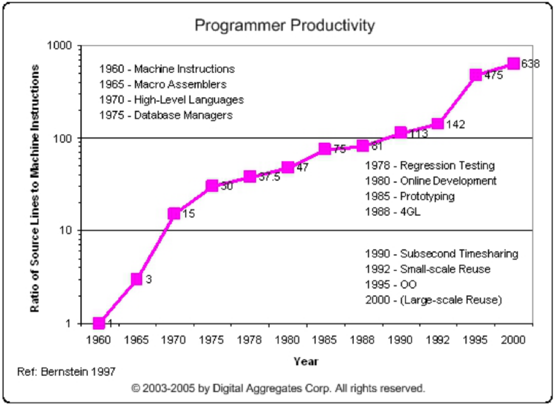
- Describe to the computer solution procedures that are completely unambiguous.
- Look at data, organization and manipulation of data, and formal languages.

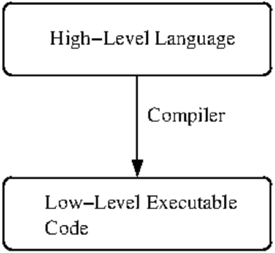
Expanding Expectations of Computing



Pathway to Improved Programmer Productivity

Increasing System Complexity: Software programmers need to find ways to solve problems at high levels of abstraction.





Evolution of Computer Languages

Computer Languages. Formal description – precise grammar – for how a problem can be solved.

Evolution. It takes about a decade for significant advances in computing to occur:

Capability	1970s	1980s	1990s
Users	Specialists	Individuals	Groups
Usage	Numerical computations	Desktop computing	E-mail, web, file transfer.
Interaction	Type at keyboard	Screen and mouse	audio/voice.
Languages	Fortran, C	MATLAB	Python, Java

Popular Computer Languages

Tend to be designed for a specific set of purposes:

- FORTRAN (1950s – today). Stands for formula translation.
- C (early 1970s – today). New operating systems.
- C++ (early 1970s – today). Object-oriented version of C.
- MATLAB (mid 1980s – today). Stands for matrix laboratory.
- Python (1990s – today). Object-oriented scripting language.
- HTML (1990s – today). Layout of web-page content.
- Java (1994 – today). Object-Oriented language for network-based computing.
- XML (late 1990s – today). Description of data on the Web.

Post- 2000 Era

Imagine: What if COVID-19 had arrived in 2000?

- No iPhone, No iPad, No iTunes.
- No Facebook, No Instagram, No WhatsApp.
- No Google Maps, No Google Streetview.
- No Dropbox, No Zoom.

Recent Advances in Technology:

- Average internet speeds: In 2000, 0.07 Mbs; In 2009, 5-7 Mbs; In 2020, 100-200 Mbs; 5G, 1000-2000 Mbs.
- Cloud-based data storage and computational services (AWS).
- New languages: Swift → App development on iPhone/iPad.
- Many new types of sensors and methods of data collection.

Post- 2000 Era

New Infrastructure → New Architectures, Languages, ...

Capability	2000-present	2020-2030
Users	Groups of people, sensors and computers.	Integration of the cyber and physical worlds.
Usage	Mobile computing. Control of physical systems. Social networking.	Embedded real-time control of physical systems.
Interaction	Touch, multi-touch, proximity.	....
Languages	XML, RDF, OWL.	New languages to support time-precise computations.

Post-2010 Era → Emergence of AI

State-of-the-Art Implementation (2020, Google, Siemens, IBM)

- AI and ML will be deeply embedded in new software and algorithms.

Artificial Intelligence:

- Knowledge representation and reasoning with ontologies and rules. Semantic graphs. Executable event-based processing.

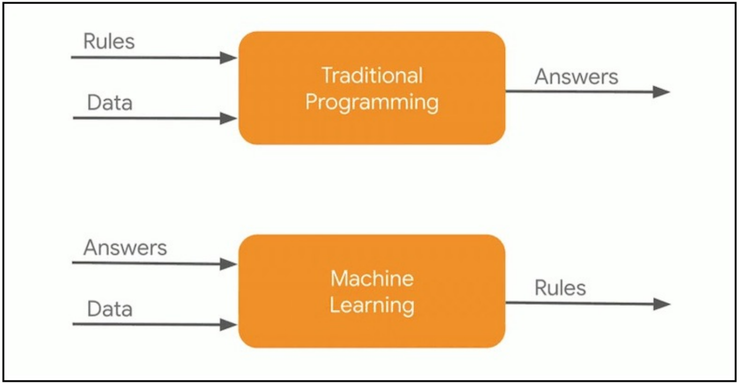
Machine Learning:

- Modern neural networks. Input-to-output prediction.
- Data mining.
- Identify objects, events, and anomalies.
- Learn structure and sequence. Remember stuff.

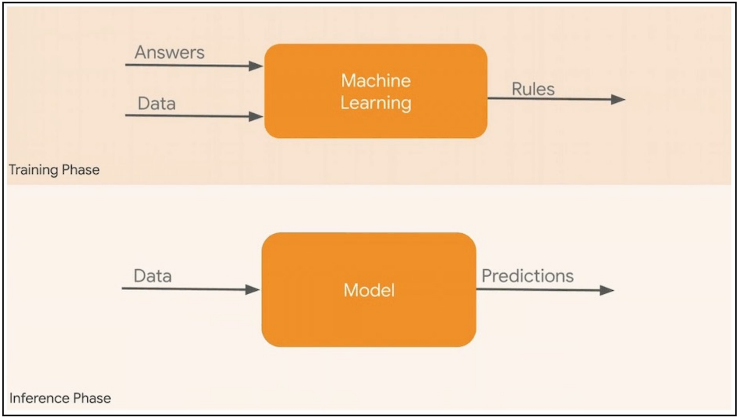
Man and Machine (AI-ML View)

Man	AI-ML Machine
• Good at formulating solutions to problems. • Can work with incomplete data and information. • Creative. • Reasons logically, but very slow. Forgetful. • Performance is static. • Humans make the rules, then they break them.	• Manipulates Os and 1s. • Can work with incomplete data and information. • Creative. • Fast logical reasoning. • Performance doubles every 18-24 months. • Data mining can discover the rules.

Traditional Programming vs AI-ML Workflow

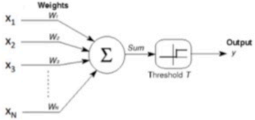


Traditional Programming vs AI-ML Workflow



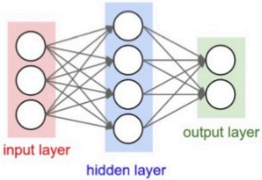
Machine Learning Capabilities (1980-1990)

Expressive Power of a Neural Network

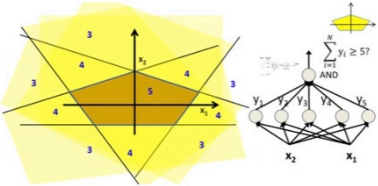


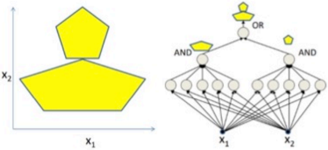
$$y = \begin{cases} 1 & \text{if} \quad \sum_{i=1}^{d} w_i x_i \geq T \\ 0 & \text{else} \end{cases}$$

Neural Network with Single Hidden Layer



Approximation of Functions / Boolean Logic





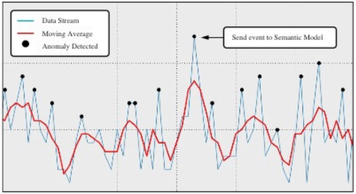
Machine Learning Capabilities (1997-2014)

Learning Streams of Text

- Download complete works of Shakespeare (5.4 million characters)
- Train machine to remember text.
- Write new Shakespeare!

```
Sample after 1000 Iterations
----------------------------

  OTHERS. Allow up, whe, Will a moutice,
  Reason thot boy Eckents alliem; comn jusgius,
  And encarnembover hath last)!
  TASTOR. When no; devires at though me beligo jody?
  MANCELOT. Trom juther and bur itnot spock,
  That as take have wendisho

Sample after 2000 Iterations
----------------------------

  VIRGTARD. Walk this boy and door as am 'stone!
  NTRURLEN. Being entainure af Haton.
  His that by much that, I mion's now, who make foll the kidl!
  CLOTE. Why which Hamm'd?
  QUICKLY. And stand quast of I; this Pi

Sample after 2500 Iterations
----------------------------

  FORD. Nay, You're, excount: and now did yet.
  PAROLLES. Take DUTBY
  This who is begin Gnoban a bows; but yet which that have be,
  Oll, thou stam, and me not ready withered gids
  And he in the pleasues or pardon us.
  Mer. I pray you, how can, and tu

Sample after 3000 Iterations
----------------------------

  Hume, 'tigoning, dear?
  My lam, an hour, chork'd more in my grain,
  I am thing forent innonion, madam! I thank I do speak you?
  ABESSITGBO. But his bosines, giving to know; foward to
  the distvesail.' The to you well know yes, my lovi.
  SECOND CMOMBOR. He needs, for the reforeds are;
```

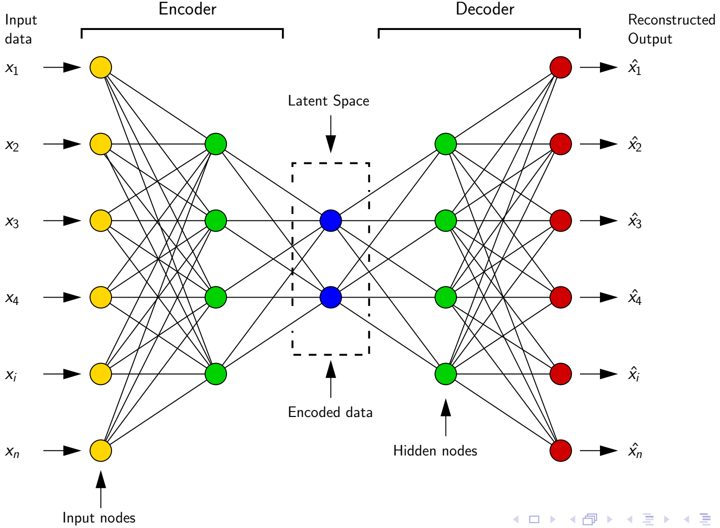
Time Series Anomaly Detection



Time Series Prediction

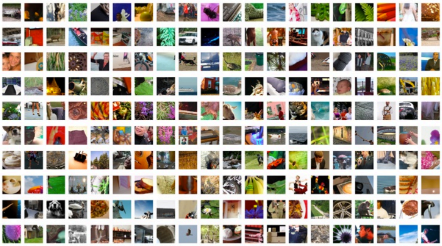
Classification of Machine Learning Problems

AutoEncoder (Encoder-Decoder-Reconstruction)



Classification of Machine Learning Problems

ImageNet and Deep Learning (2009-present)



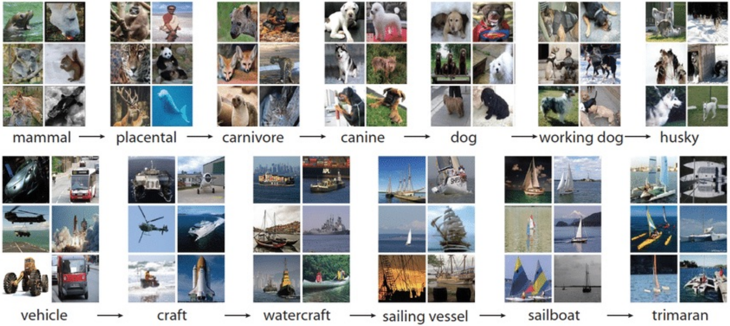
Indexed Database of 14.2 million Images

- Project initiated by Fei Fei Li in 2006
- Image annotation process crowd sourced via Amazon's Mechanical Turk. Categories derived from WordNet.
- Well organized → supervised machine learning.

Classification of Machine Learning Problems

ImageNet and Deep Learning Capabilities:

- Identify objects in an image.
- 27 high-level categories; 21,800 sub-categories.



ImageNet and Deep Learning

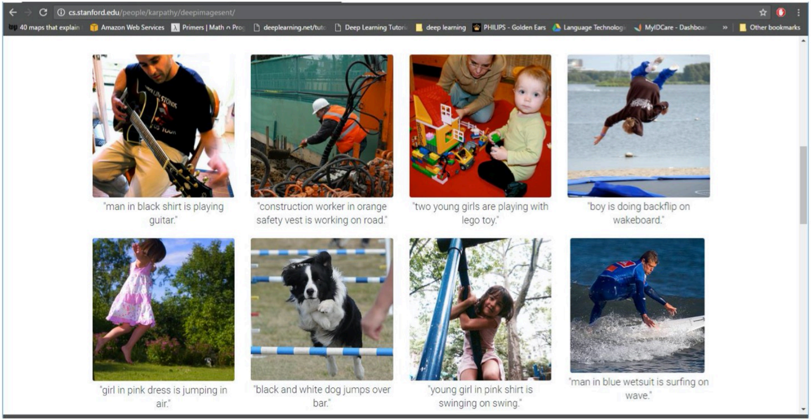
Capabilities (2018):

- Identify relationship among multiple objects in a image.

Example. Dog riding skateboard

ImageNet and Deep Learning

Captions generated by a neural network:



Machine Learning at Scale

Object-recognition module:

- 24 million nodes.
- 140 million parameters.
- 15 billion connections.

Source: Fei Fei Li, TEDTalk, YouTube 2015.

Machine Learning in CEE

Opportunities for Machine Learning in CEE:

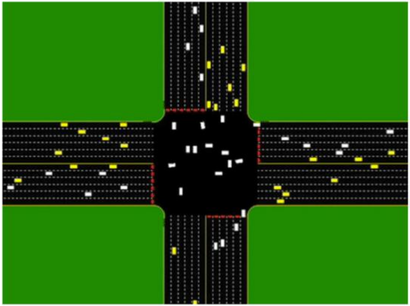
- Predicting system response and performance.
- Interpreting data and formulating models to predict component and subsystem-level properties.
- Information retrieval from images and text.
- Recognizing patterns in streams of sensed data.

Economic Considerations:

- Urban infrastructure is permanent/semi-permanent and very expensive to build and maintain.
- Prioritize improvements to efficiency by identifying and removing bottlenecks in performance.
- Use AI-ML for design of actions that enhance behavior/system performance.

AI-ML Enabled Decision Making (Self-Driving Cars)

Goal. Improve performance by removing bottlenecks → no human driver; no traffic lights.



Remark: 95% of the requirements are for the system software.

Source: ISR visitor from GM Research.

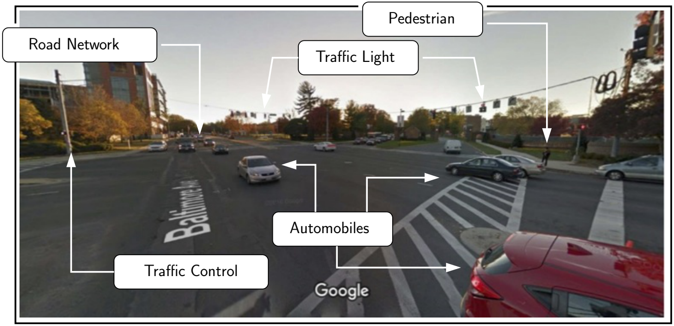
Remark: Tesla will produce self-driving cars by 2016.

Source: Elon Musk.

Stop signs and traffic lights are replaced by mechanisms for vehicle-to-vehicle communication (Adapted from http:citylab.com).

AI-ML Enabled Decision Making (Self-Driving Cars)

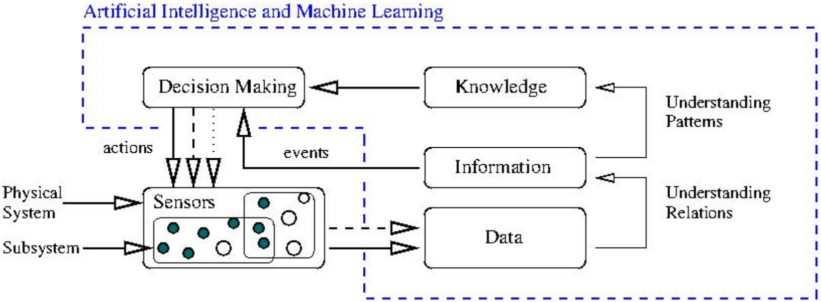
Goal. How to traverse traffic intersection safely and without causing an accident?



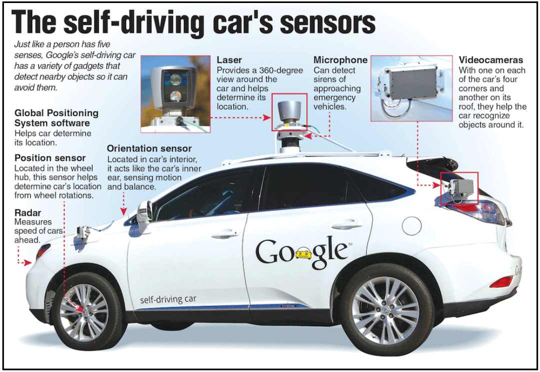
Required Capability. Observe, evaluate, reason, take actions.
Challenges. Multiple domains, multiple streams of heterogeneous data, event-driven behavior, dynamic, time critical.

AI-ML Enabled Decision Making (Self-Driving Cars)

Pathway from sensing and data collection to ... action ... improved performance, now enabled by AI and ML capabilities:



AI-ML Enabled Decision Making (Self-Driving Cars)



Today: Modern automobiles → 100 million lines of software.
Tomorrow: Self-Driving automobiles → 200-300 million lines of software.

AI-ML Enabled Decision Making (Self-Driving Cars)

Navigating a Busy Traffic Intersection:

- Identify various kinds of objects (e.g., vehicles, crosswalk).
- Predict what objects will do next.
- Conduct safety assessment.
- Take action.

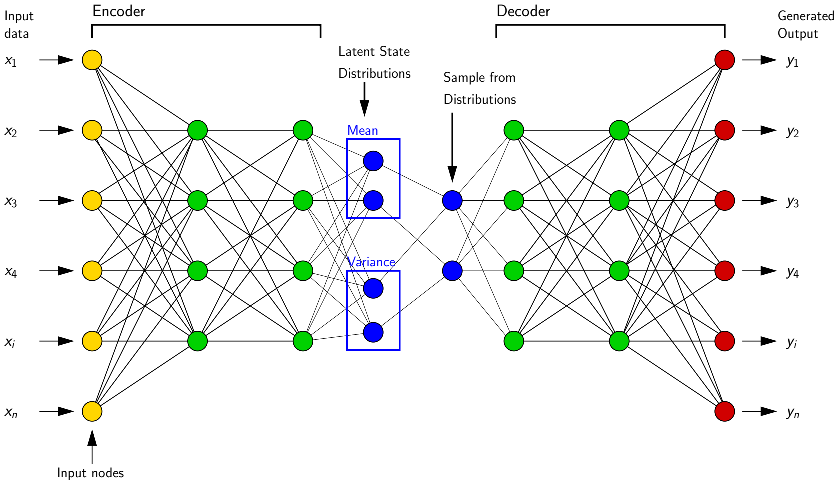
Google DeepMind (2018-2020)

Teach Self-Driving Cars to Navigate a City without a Map

Test Cities: London, Paris, New York.

Post-2020 Era → Explosion of Generative AI

Variational AutoEncoders (Generative Models)

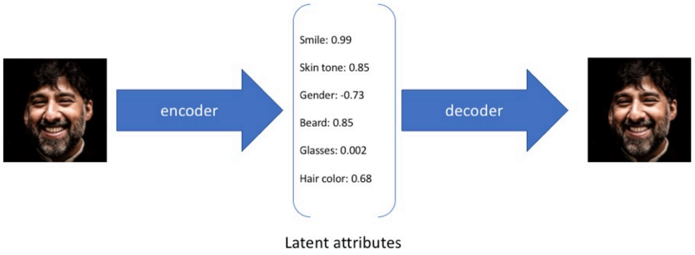


Post-2020 Era → Explosion of Generative AI

Standard Autoencoders vs. Variational Autoencoders:

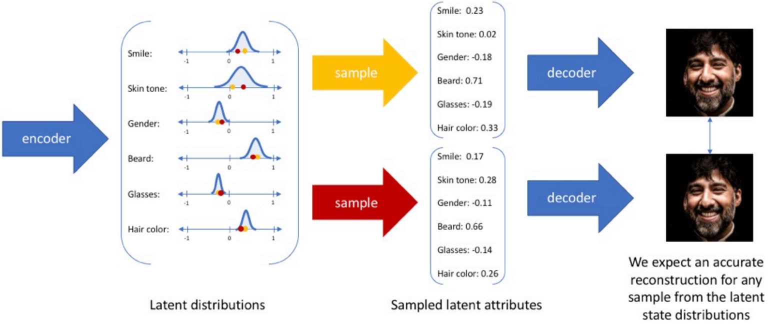
- A standard autoencoder outputs a single value for each encoding dimension.
- Variational autoencoders provide a probability distribution for each latent attribute.

Example: Single value representations for latent attributes:



Post-2020 Era → Explosion of Generative AI

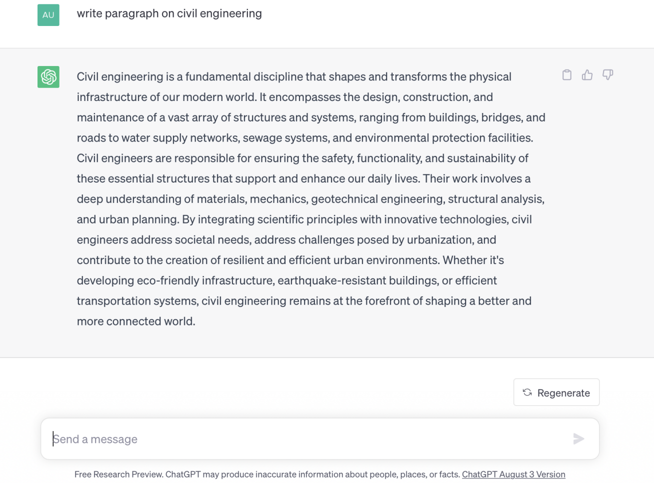
Image Reconstruction: sampled from latent distributions ...



Source: Jordan J., Variational Autoencoders, Data Science, March 2018.

Post-2020 Era → ChatGPT

ChatGPT: Generative Pre-Trained Transformer



Post-2020 Era → ChatGPT

AU integrate sin(3x)*sin(2x) dx

To integrate the expression ∫sin(3x) * sin(2x) dx, we can use the product-to-sum trigonometric identity, which states that:

sin(A) * sin(B) = (1/2) * [cos(A - B) - cos(A + B)].

Using this identity, we can rewrite the integral as:

∫sin(3x) * sin(2x) dx = (1/2)∫[cos(3x - 2x) - cos(3x + 2x)] dx
= (1/2)∫[cos(x) - cos(5x)] dx.

Now, we can integrate each term separately:

∫cos(x) dx = sin(x) + C1,

∫cos(5x) dx = (1/5)sin(5x) + C2.

Putting it all together:

∫sin(3x) * sin(2x) dx = (1/2) * [sin(x) + C1 - (1/5)sin(5x) - C2]
= (1/2) * [sin(x) - (1/5)sin(5x)] + (C1/2 - C2).

So, the integral of sin(3x) * sin(2x) with respect to x is:

∫sin(3x) * sin(2x) dx = (1/2) * [sin(x) - (1/5)sin(5x)] + C,
where C = C1/2 - C2 is the constant of integration.

Regenerate

Post-2020 Era → AI Generated Architecture

Convergence: Engineering-Architecture-AI

AI-generated art …

AI-generated building architecture

Post-2020 Era → AI Generated Presentation

RT
Russian TV channel unveils AI weather ...

DayFR Euro
AI weather forecaster

References

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