Machine Learning Basics

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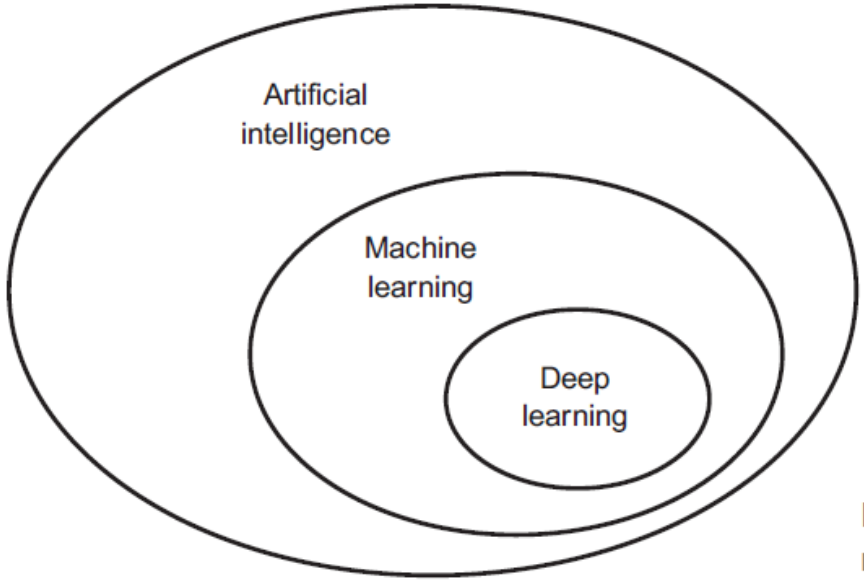
AI, machine learning, and deep learning

- How do they relate to each other?



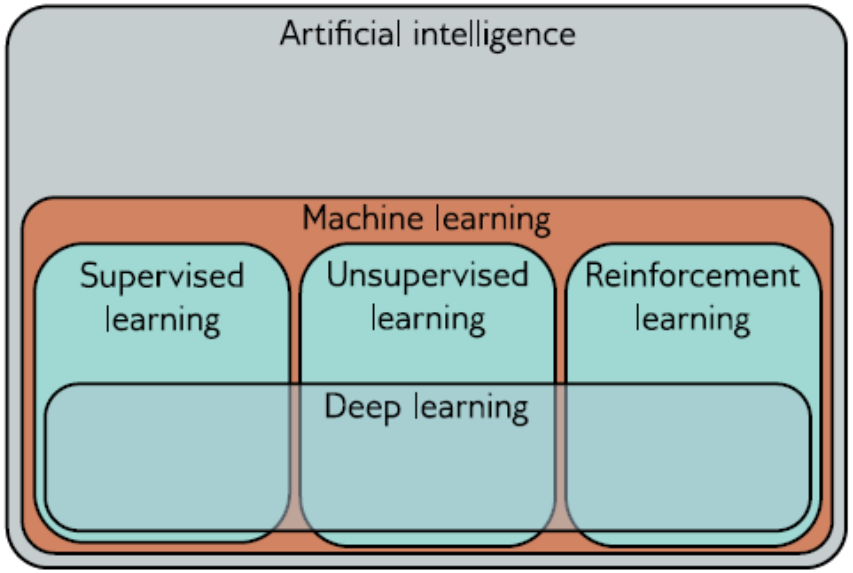


Figure 1.1 Artificial intelligence, machine learning, and deep learning

AI, machine learning, and deep learning

- Artificial intelligence
  - Motivation: whether computers could be made to “think”
  - *The effort to automate intellectual tasks normally performed by humans*
  - It encompasses machine learning and deep learning, but it also includes many more approaches that don’t involve any learning.
  - For a long time, many experts believed that human-level AI could be achieved by programming a sufficiently large set of explicit rules → *symbolic AI* → *expert systems*
  - Symbolic AI can solve well-defined, logical problems. But, it turned out to be intractable to figure out explicit rules for solving more complex problems.

AI, machine learning, and deep learning

- Machine learning
  - From Wikipedia,

> **Machine learning** is a subfield of computer science that evolved from the study of pattern recognition and computational learning theory in artificial intelligence. Machine learning explores the construction and study of **algorithms that can learn from and make predictions on data**. Such algorithms operate by building a model from example inputs in order **to make data-driven predictions or decisions**, rather than following strictly static program instructions.

AI, machine learning, and deep learning

- Machine learning
  - Could a computer learn on its own how to perform a specified task? Could a computer automatically learn data-processing rules by looking at data?
  - A new programming paradigm

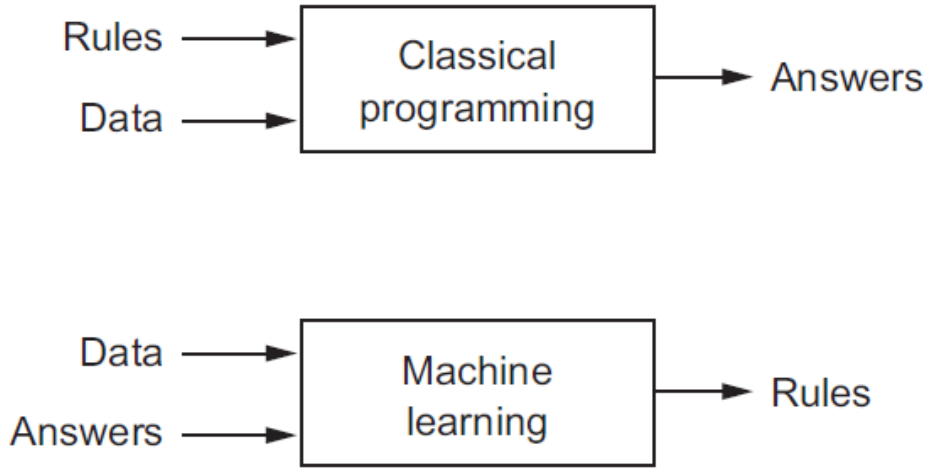


Figure 1.2 Machine learning: a new programming paradigm

AI, machine learning, and deep learning

- What do we mean by learning?

> *"A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E"*
>
> *from Mitchell (1997)*

AI, machine learning, and deep learning

- The task, *T*
  - If we want a robot to be able to walk, then walking is the task.
  - Classification, regression, anomaly detection, machine translation, structured output, etc.
  - Classification
    - specify which of *k* categories some input belongs to.
    - To solve this task, we need a function $f: \mathbb{R}^n \rightarrow \{1, \ldots, k\}$.
  - Regression
    - predict a numerical value given some input.
    - To solve this task, we need a function $f: \mathbb{R}^n \rightarrow \mathbb{R}$.

AI, machine learning, and deep learning

- The task, *T*
  - Transcription
    - observe unstructured representation of data and transcribe the information into discrete textual form.
    - OCR (optical character recognition), speech recognition, etc.
  - Machine translation
  - Structured output
    - task where the output is a vector with important relationships between elements.
    - transcription, translation, parsing, segmentation, etc.
  - Anomaly detection

AI, machine learning, and deep learning

- The performance measure, *P*
  - A quantitative measure of the performance to evaluate the abilities of a ML algorithm
  - Accuracy, error rate, the average log-probability, etc.
  - It is often difficult to choose a performance measure that corresponds well to the desired behavior of the system.
    - For a regression task, should we penalize the system more if it frequently makes medium-sized mistakes or if it rarely makes very large mistakes?
  - In some cases, measuring the quantity is impractical.

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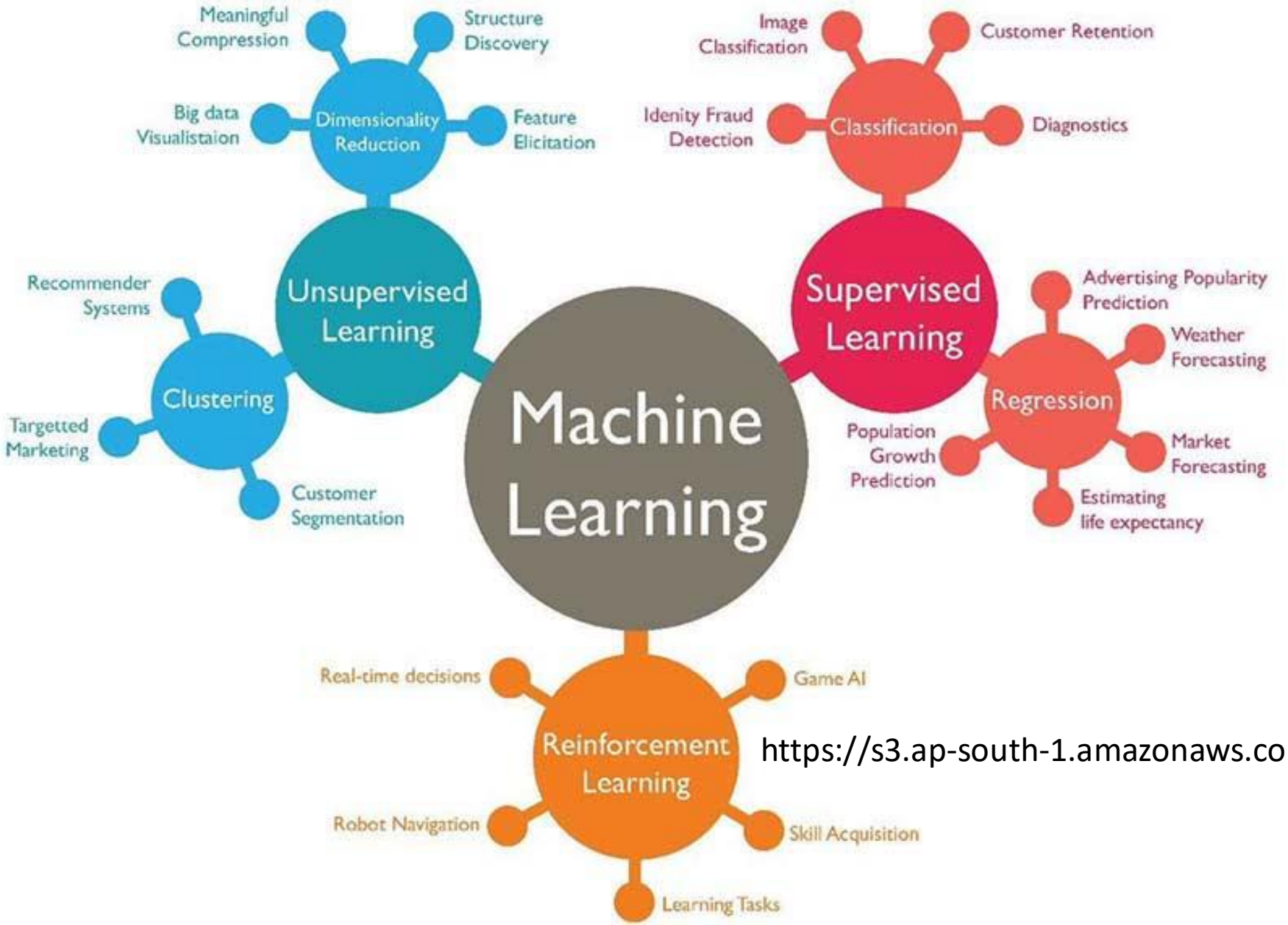
- The experience, *E*
  - Experience to have during the learning process → unsupervised/supervised

Unsupervised learning	Supervised learning
Experience a dataset containing many features, then learn useful properties of the structure of this dataset	Experience a dataset containing features, but each example is also associated with a label or target
Observe several examples of $\boldsymbol{x}$ → (implicitly or explicitly) learn the probability dist. $p(\boldsymbol{x})$	Observe several examples of $(\boldsymbol{x}, \boldsymbol{y})$ → learn to predict $\boldsymbol{y}$ from $\boldsymbol{x}$ by estimating $p(\boldsymbol{y}\|\boldsymbol{x})$
$p(\boldsymbol{x}) = \prod_{i=1}^{n} p(x_i \| x_1, \ldots, x_{i-1})$	$\Longleftrightarrow$ $p(y\|\boldsymbol{x}) = \frac{p(\boldsymbol{x}, y)}{\sum_{y'} p(\boldsymbol{x}, y')}$



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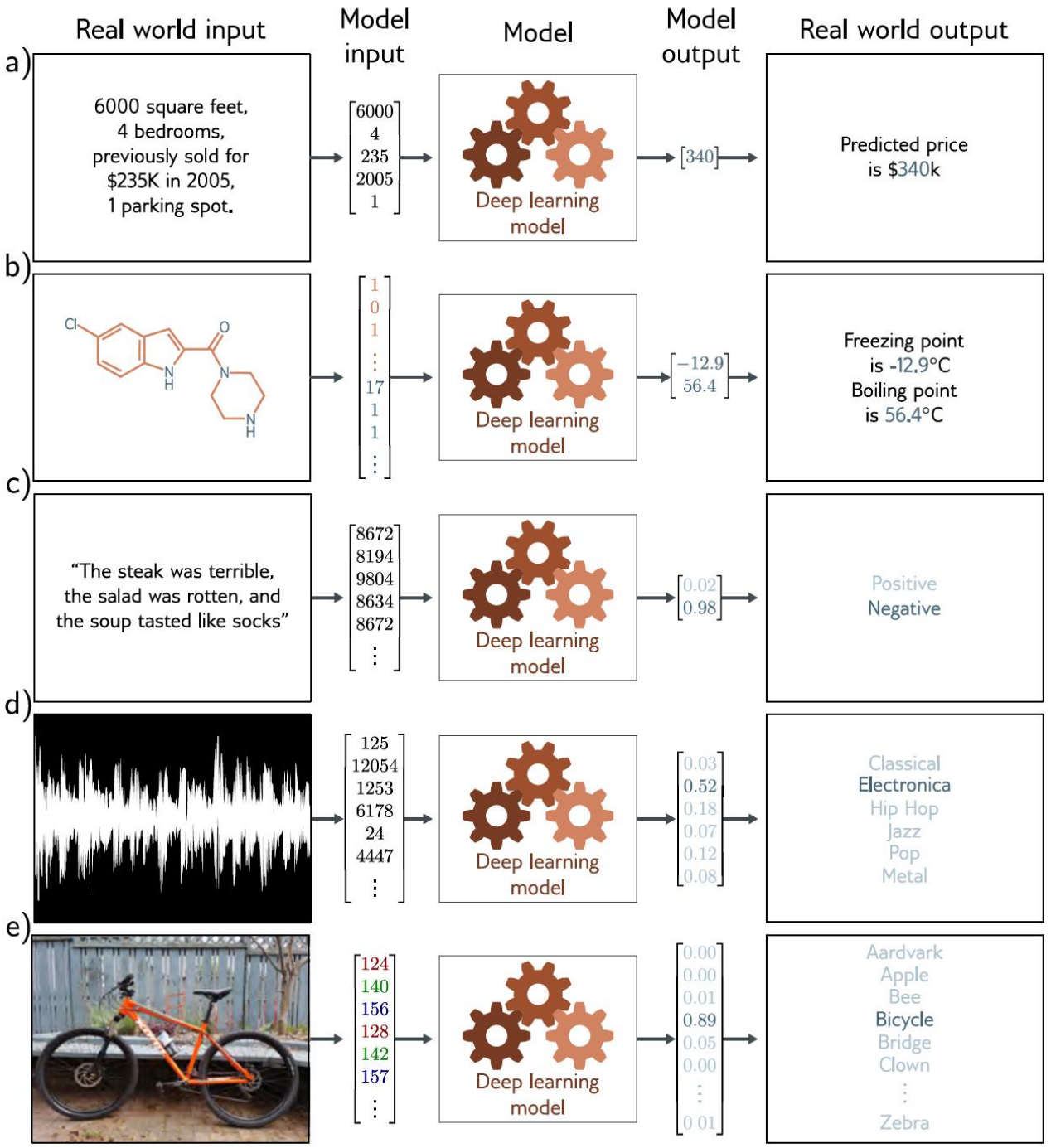
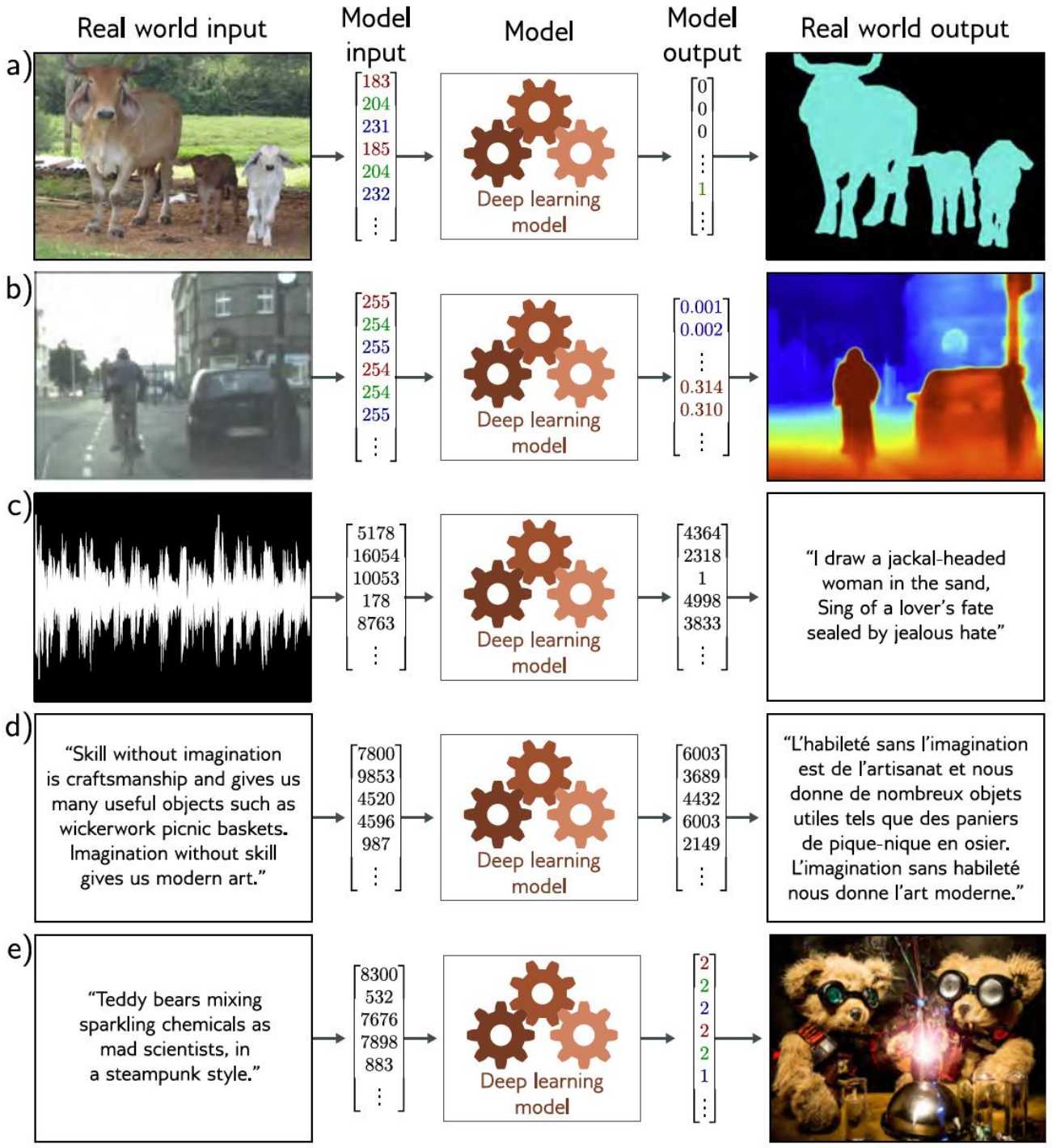
Supervised learning tasks
: regression and classification



Supervised learning tasks : structured outputs



Unsupervised learning tasks
: generative models

Figure 1.5 Generative models for images. Left: two images were generated from a model trained on pictures of cats. These are not real cats, but samples from a probability model. Right: two images generated from a model trained on images of buildings. Adapted from Karras et al. (2020b).

Unsupervised learning tasks
: generative models

The moon had risen by the time I reached the edge of the forest, and the light that filtered through the trees was silver and cold. I shivered, though I was not cold, and quickened my pace. I had never been so far from the village before, and I was not sure what to expect. I had been walking for hours, and I was tired and hungry. I had left in such a hurry that I had not thought to pack any food, and I had not thought to bring a weapon. I was unarmed and alone in a strange place, and I did not know what I was doing.

I had been walking for so long that I had lost all sense of time, and I had no idea how far I had come. I only knew that I had to keep going. I had to find her. I was getting close. I could feel it. She was nearby, and she was in trouble. I had to find her and help her, before it was too late.

Figure 1.6 Short story synthesized from a generative model of text data. The model describes a probability distribution that assigns a probability to every output string. Sampling from the model creates strings that follow the statistics of the training data (here, short stories) but have never been seen before.

Unsupervised learning tasks
: generative models

Figure 1.7 Inpainting. In the original image (left), the boy is obscured by metal cables. These undesirable regions (center) are removed and the generative model synthesizes a new image (right) under the constraint that the remaining pixels must stay the same. Adapted from Saharia et al. (2022a).

AI, machine learning, and deep learning

- Machine learning
  - A ML system is *trained* rather than explicitly programmed.
    - It sees many examples relevant to a task, and it finds useful structure in them. → learns rules for automating the task!
  - It has quickly become the most popular and most successful subfield of AI. → driven by faster hardware and larger datasets
  - Machine learning, and especially deep learning, is engineering oriented.

Reading assignment

- “Understanding DL” book
  - Chapter 1. Introduction
- “Dive into DL” material
  - Chapter 1. Introduction: https://d2l.ai/chapter_introduction/index.html