

There is no AI without Deep Generative Modelling

Jakub M. Tomczak

What is **intelligence**?

What is **intelligence**?

...

What is **intelligence**?

...

What is **artificial intelligence**?

INFORMATION, INTELLIGENCE AND ARTIFICIAL INTELLIGENCE

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What is **artificial intelligence**?



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Decision/action



Information



INFORMATION, INTELLIGENCE AND ARTIFICIAL INTELLIGENCE

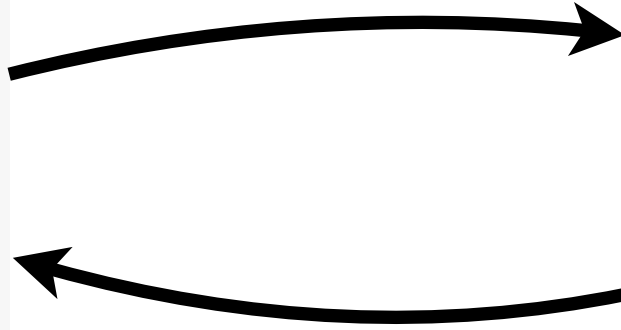
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Decision/action



Information

0001101010011...

What is **artificial intelligence**?

- **Information** processing
- **Information** storing
- **Information** transmission



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Learning
Knowledge representation
Models...



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The question is how to formalize the problem of AI?

Information (a quick recap)



Claude Shannon

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$$\mathbb{H}[x] = - \sum_x p(x) \log p(x)$$



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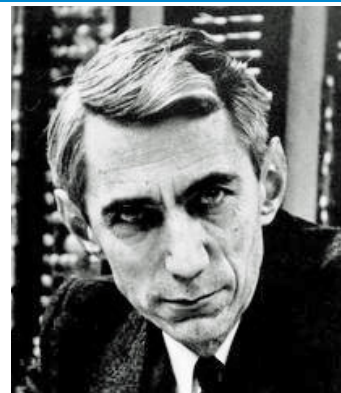
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Entropy is max if all x 's are equiprobable.

Entropy is min if the probability of one value is 1.



Claude Shannon

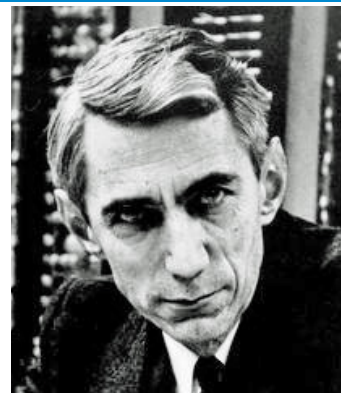
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Optimal message length \approx the entropy.



Claude Shannon

Information (a quick recap)

We have two random sources: x and y .

We can quantify the **uncertainty** of them by calculating **the joint entropy**:

$$\mathbb{H}[x, y] = - \sum_{x, y} p(x, y) \log p(x, y)$$

or **the conditional entropy**:

$$\mathbb{H}[y | x] = - \sum_{x, y} p(x, y) \log p(y | x)$$



Claude Shannon

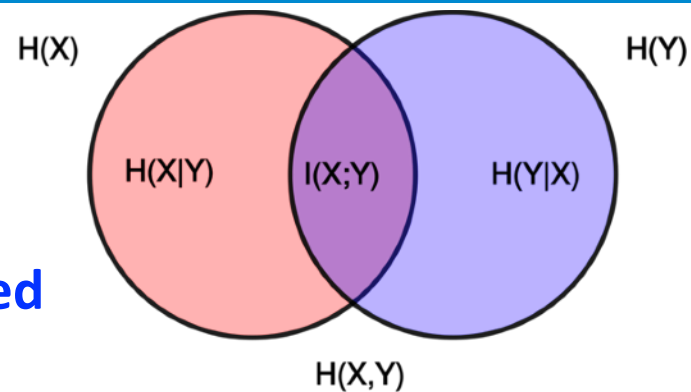
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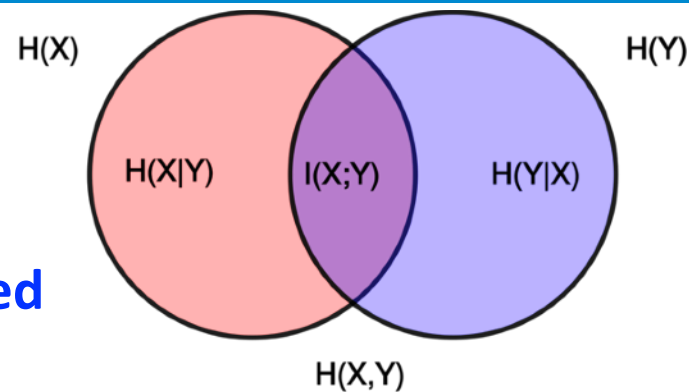


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or **how much knowing one source reduces uncertainty about the other.**

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The **goal** of AI is to **maximize** the **mutual information** between (x, y) and m :


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Entropy of the world
(model has no influence on that)



That's the “real” goal!

The **goal** of AI is to **maximize** the **mutual information** between (x, y) and m

(or minimize $\mathbb{H}[x, y | m]$, i.e., minimize uncertainty of the world):

$$\mathbb{H}[x, y | m] = \sum_{x, y, m} p(x, y, m) [\log p(y | x, m) + \log p(x | m)]$$


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A model for
decision making



A model for
understanding
the world.

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In order to achieve that, AI should focus on learning **two models**:

- **A model for decision making:** $p(y | x, m)$
- **A model for understanding the world:** $p(x | m)$

WHAT HAPPENS IF WE LEARN ONLY DECISION MAKING

The bulk of AI is focused on the decision making part **only!**

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Example: Let's say we have a model that is well trained.



$$\begin{aligned}p(y = \text{cat}|\mathbf{x}) &= 0.90 \\p(y = \text{dog}|\mathbf{x}) &= 0.05 \\p(y = \text{horse}|\mathbf{x}) &= 0.05\end{aligned}$$

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+



noise

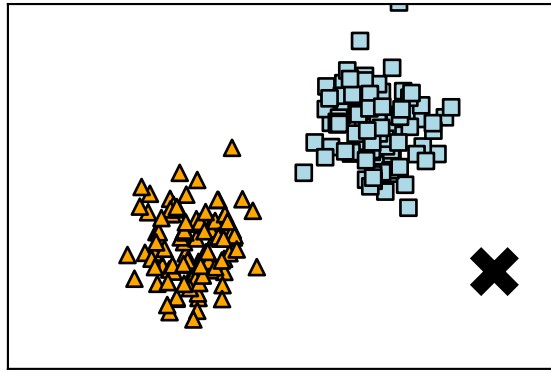
=



$p(y = \text{cat}|\mathbf{x}) = 0.05$
 $p(y = \text{dog}|\mathbf{x}) = 0.05$
 $p(y = \text{horse}|\mathbf{x}) = 0.90$

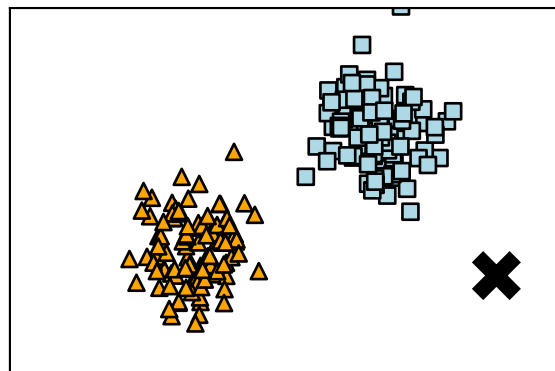
But after adding a little noise it could fail completely...

DEEP GENERATIVE MODELING: WHY DO WE NEED THEM?

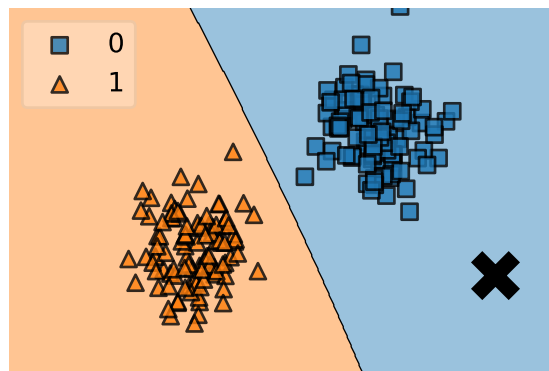


Data

DEEP GENERATIVE MODELING: WHY DO WE NEED THEM?



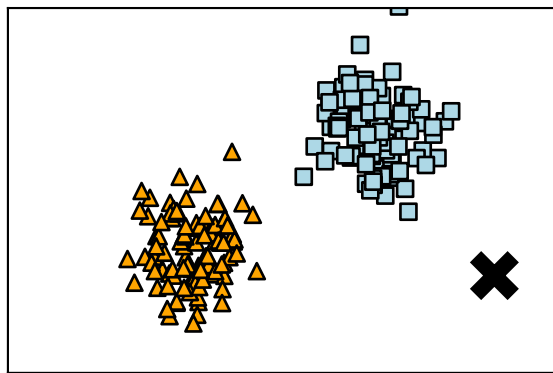
Data



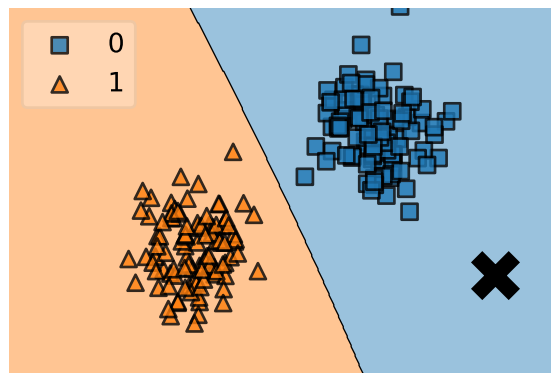
$p(y|\mathbf{x})$

$p(\text{blue}|\mathbf{x})$ is high
= certain decision!

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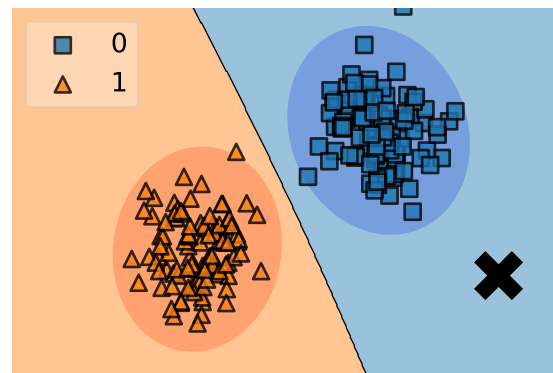


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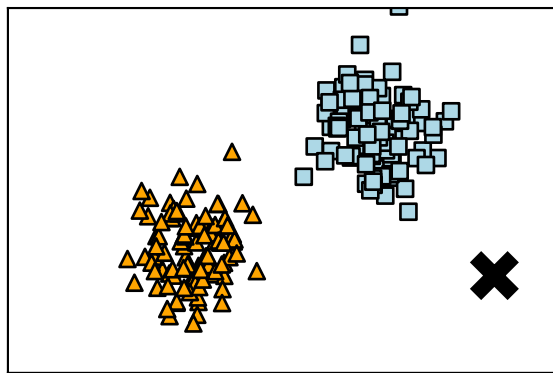
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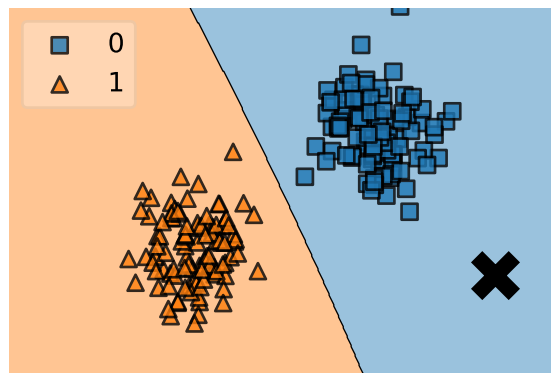
$p(\mathbf{x}, y) = p(y|\mathbf{x}) p(\mathbf{x})$

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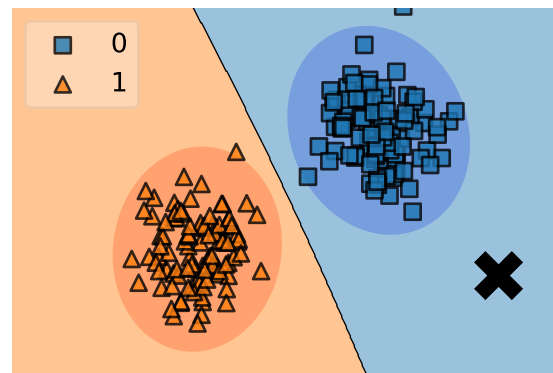


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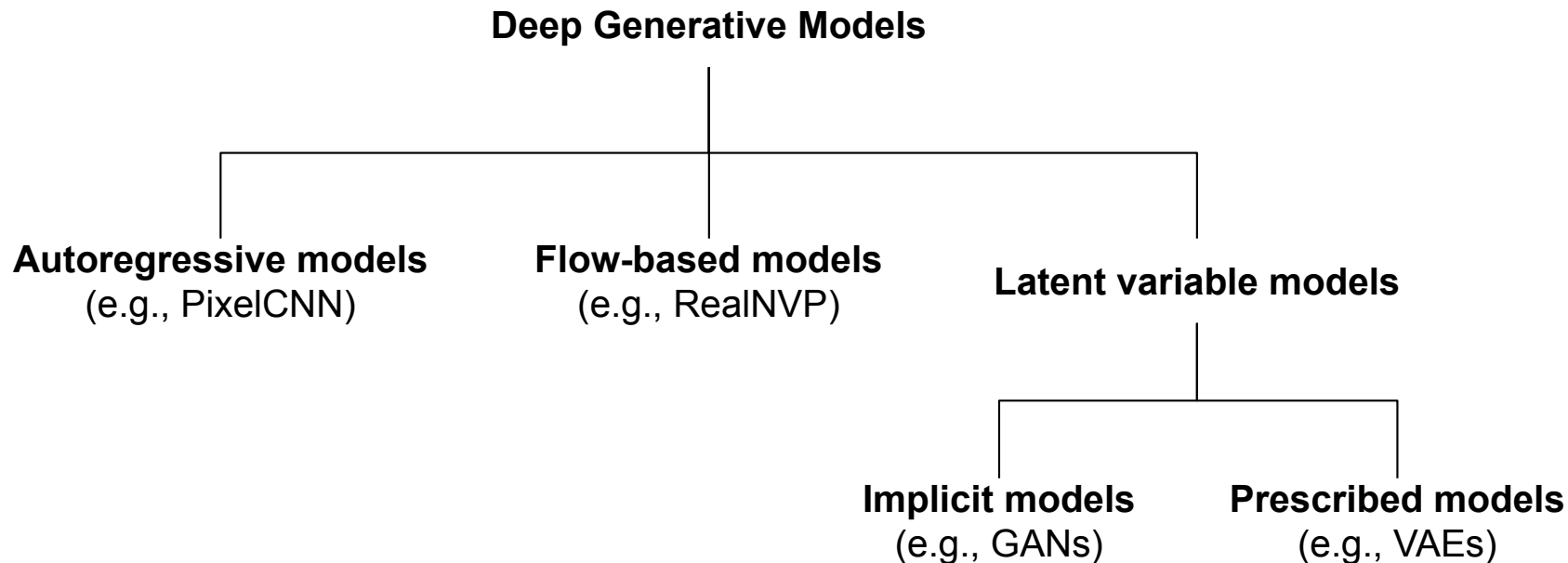


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Thus, learning the conditional is only a part of the story!
How can we learn $p(\mathbf{x})$?

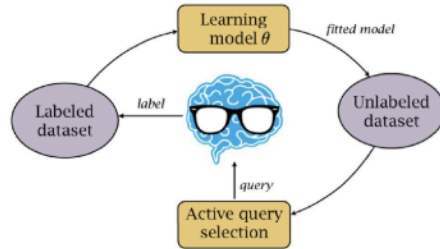
DEEP GENERATIVE MODELING: HOW WE CAN FORMULATE IT?



DEEP GENERATIVE MODELING: WHERE CAN WE USE IT?

" i want to talk to you . "
" i want to be with you . "
" i do n't want to be with you . "
i do n't want to be with you .
she did n't want to be with him .
he was silent for a long moment .
he was silent for a moment .
it was quiet for a moment .
it was dark and cold .
there was a pause .
it was my turn .

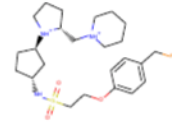
Text analysis



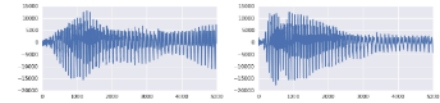
Active Learning



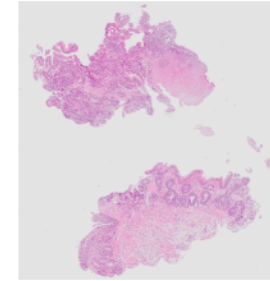
Image analysis



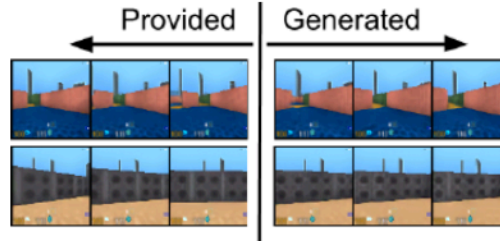
Graph analysis



Audio analysis



Medical data



Reinforcement Learning

and more...

- A decision making model is **fine** but it doesn't bring us closer to true* AI.
- **Understanding** reality and properly **quantifying uncertainty** is **crucial** in AI.

If you are interested in going deeper into deep generative modeling, please take a look at my blog: [\[Blog\]](#)

- **Intro:** [\[Link\]](#)
- **ARMs:** [\[Link\]](#)
- **Flows:** [\[Link\]](#), [\[Link\]](#)
- **VAEs:** [\[Link\]](#), [\[Link\]](#)
- **Hybrid modeling:** [\[Link\]](#)

THANK YOU FOR YOUR ATTENTION

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