Lecture Five: Empirical Approaches

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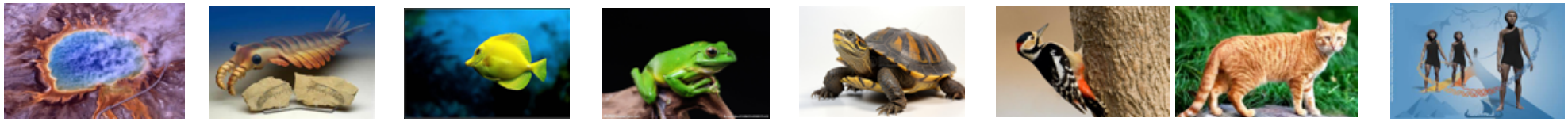
Empirical Approaches: emulating the neural system

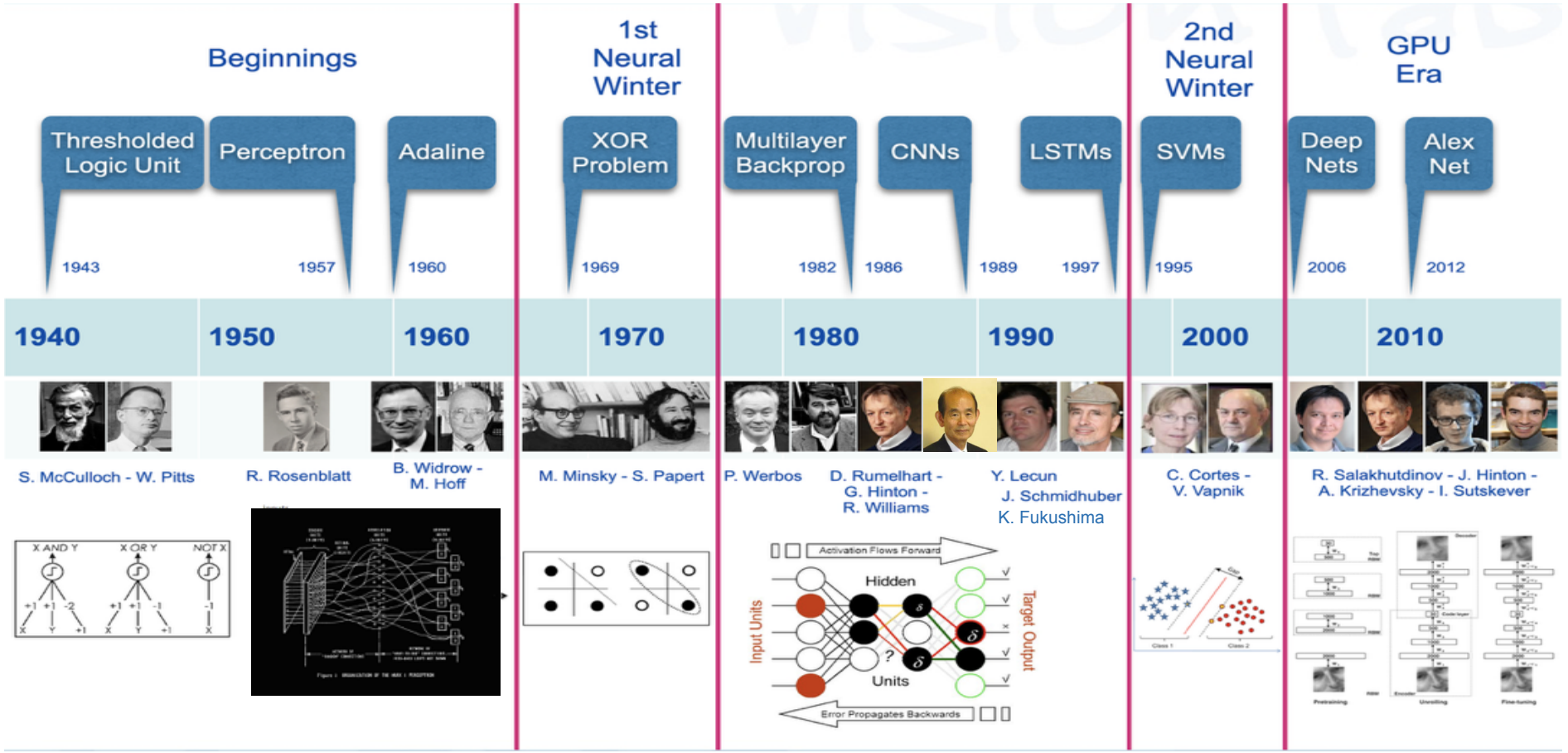
The evolution of intelligence in nature:

From Phylogenetic **To Ontogenetic**



The more advanced intelligence relies more on lifetime learning.

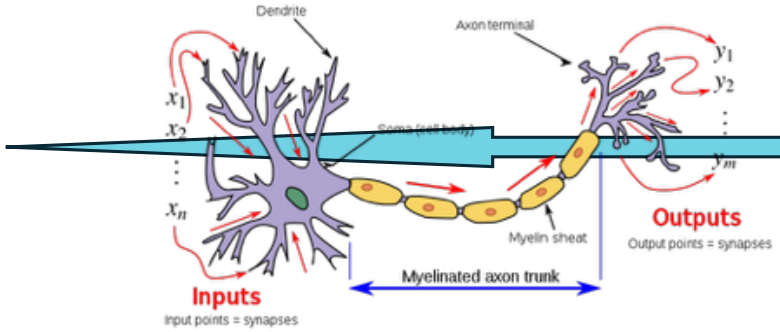
Empirical Approaches: emulating the neural system



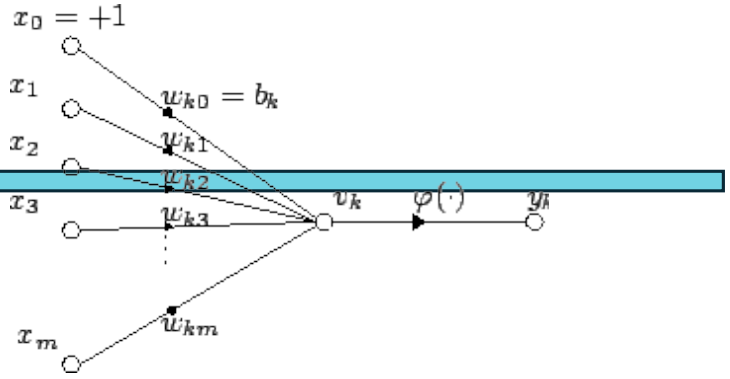
Empirical Approaches: the imitation game

A mathematical model of a neuron: an artificial neuron

Golgi and Cajal 1888 (1901 Nobel Prize)



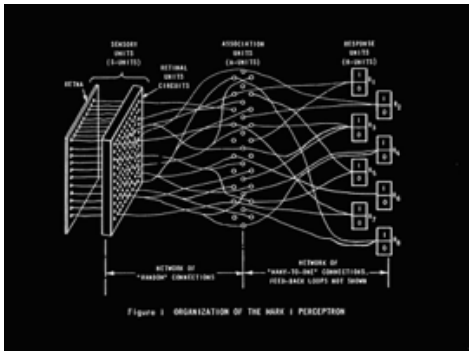
Warren McCulloch & Walter Pitts 1948

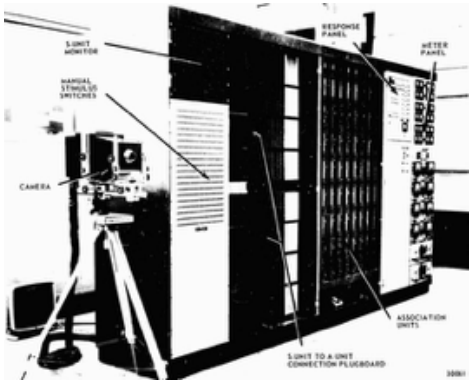


Empirical Approaches: the imitation game

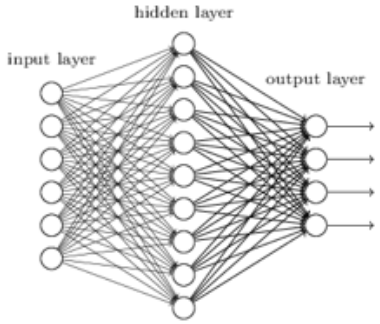
The Mark I Perceptron

Frank Rosenblatt, 1950s





"Non-deep" feedforward neural network



New York Times,
July 13, 1958

Eléctronic 'Brain' Teaches Itself

The Navy last week demonstrated the embryo of an electronic computer named the Perceptron which, when completed in about a year, is expected to be the first non-living mechanism able to "perceive, recognize and identify its surroundings without human training or control." Navy officers demonstrating a preliminary form of the device in Washington said they hesitated to call it a machine because it is so much like a "human being without life."

Dr. Frank Rosenblatt, research psychologist at the Cornell Aeronautical Laboratory, Inc., Buffalo, N. Y., designer of the Perceptron, conducted the demonstration. The machine, he said, would be the first electronic device to think as the human brain. Like humans, Perceptron will make mistakes at first, "but it will grow wiser as it gains experience," he said.

The first Perceptron, to cost about $100,000, will have about 1,000 electronic "association cells" receiving electrical impulses from an eyelike scanning device with 400 photocells. The human brain has ten billion responsive cells, including 100,000,000 connections with the eye.

Difference Recognized

The concept of the Perceptron was demonstrated on the Weather Bureau's $2,000,000 IBM 704 computer. In one experiment, the 704 computer was shown 100 squares situated at random either on the left or the right side of a field. In 100 trials, it was able to "say" correctly ninety-seven times whether a square was situated on the right or left. Dr. Rosenblatt said that after having seen only thirty to forty squares the device had learned to recognize the difference between right and left, almost the way a child learns.

When fully developed, the Perceptron will be designed to remember images and information it has perceived itself, whereas ordinary computers remember only what is fed into them on punch cards or magnetic tape.

Later Perceptrons, Dr. Rosenblatt said, will be able to recognize people and call out their names. Printed pages, longhand letters and even speech commands are within its reach. Only one more step of development, a difficult step, he said, is needed for the device to hear speech in one language and instantly translate it to speech or writing in another language.

Self-Reproduction

In principle, Dr. Rosenblatt said, it would be possible to build Perceptrons that could reproduce themselves on an assembly line and which would be "conscious" of their existence.

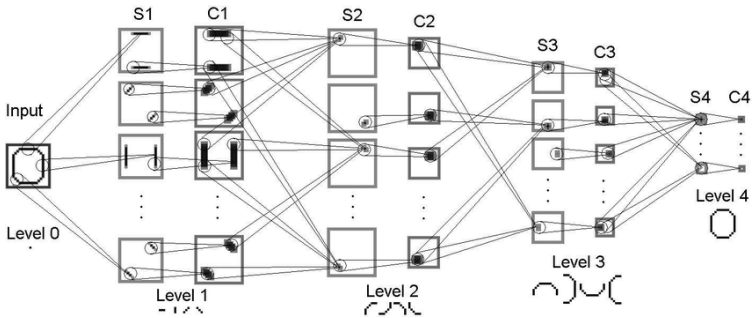
Perceptron, it was pointed out, needs no "priming." It is not necessary to introduce it to surroundings and circumstances, record the data involved and then store them for future comparison as is the case with present "mechanical brains." It literally teaches itself to recognize objects the first time it encounters them. It uses a camera-eye lens to scan objects or survey situations, and an electrical impulse system, patterned point-by-point after the human brain does the interpreting.

The Navy said it would use the principle to build the first Perceptron "thinking machines" that will be able to read or write.

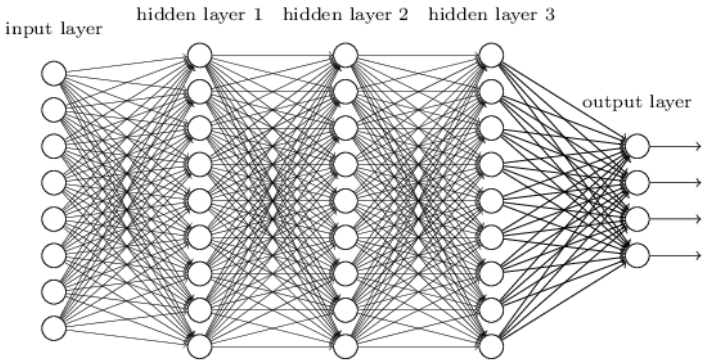
Empirical Approaches: the imitation game

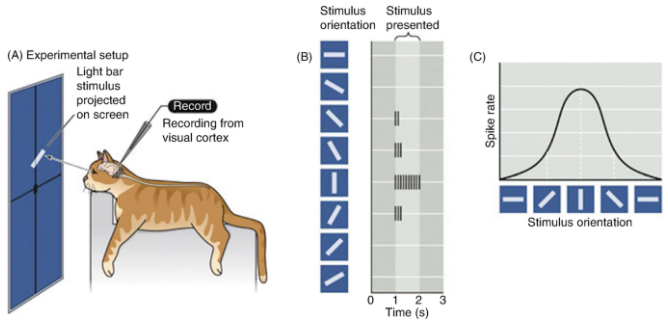
Neocognitron

Kunihiko Fukushima
1980



Deep neural network



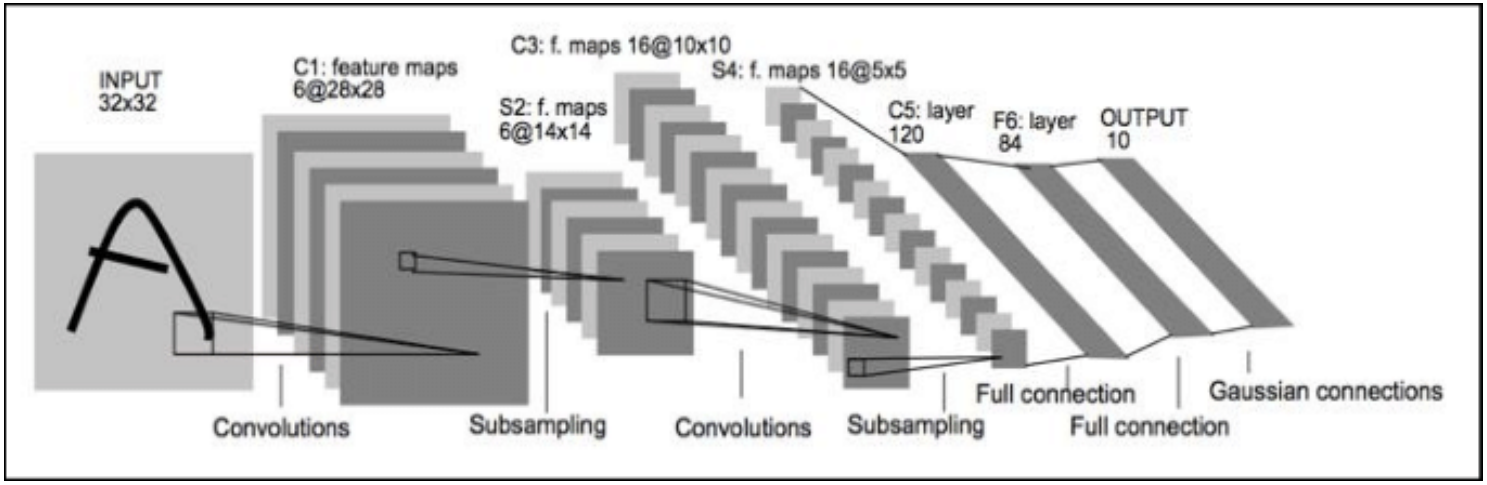


Hubel and Wiesel 1959 (1981 Nobel Prize)

Empirical Approaches

LeNet (Convolution Neural Network)

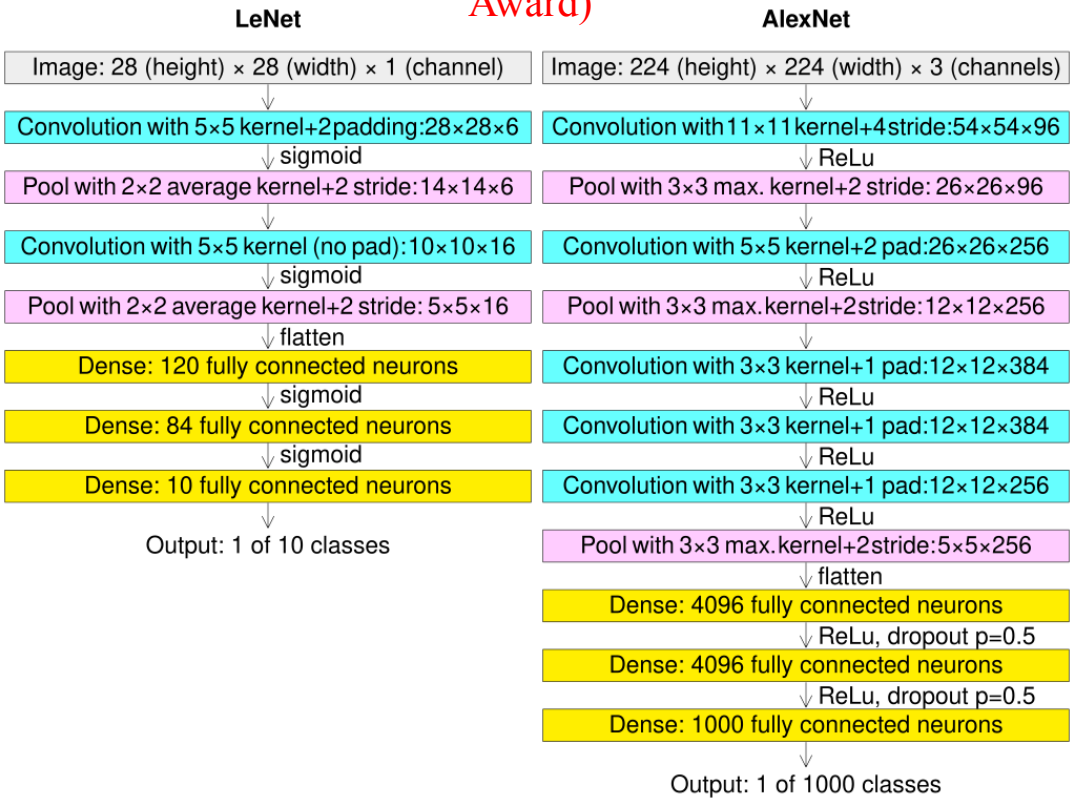
LeCun 1989 (Turing Award)



Empirical Approaches

AlexNet (Convolution Neural Network)

Alex Krizhevsky, Ilya Sutskever, Geoffrey E. Hinton, 2012 (Turing Award)



Empirical Approaches

Back Propagation (BP)

$$g(x) := f^L(W^L f^{L-1}(W^{L-1} \cdots f^1(W^1 x) \cdots))$$

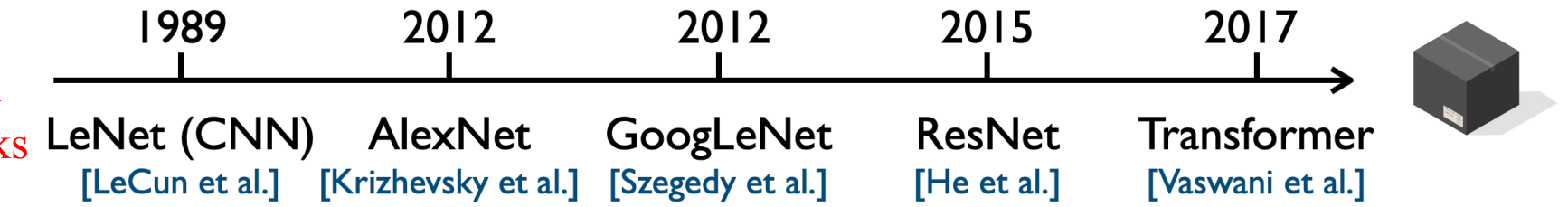
$$C(y, f^L(W^L f^{L-1}(W^{L-1} \cdots f^2(W^2 f^1(W^1 x)) \cdots)))$$

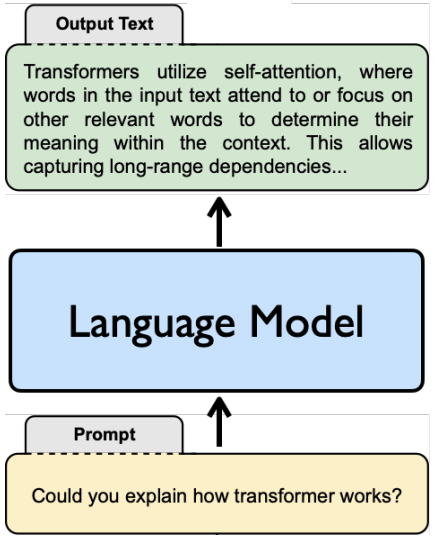
$$\frac{dC}{da^L} \cdot \frac{da^L}{dz^L} \cdot \frac{dz^L}{da^{L-1}} \cdot \frac{da^{L-1}}{dz^{L-1}} \cdot \frac{dz^{L-1}}{da^{L-2}} \cdot \ldots \cdot \frac{da^1}{dz^1} \cdot \frac{\partial z^1}{\partial x}$$

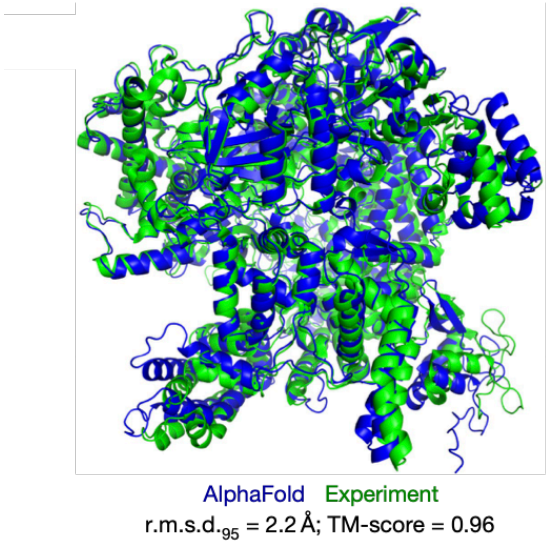
$$\frac{dC}{da^L} \circ (f^L)' \cdot W^L \circ (f^{L-1})' \cdot W^{L-1} \circ \cdots \circ (f^1)' \cdot W^1.$$

Empirical Approaches

Deep Neural Networks

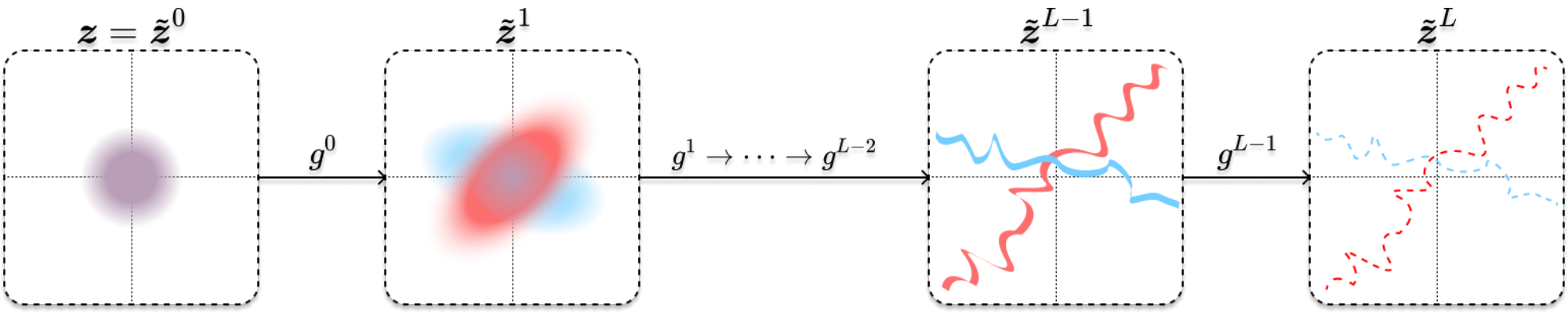






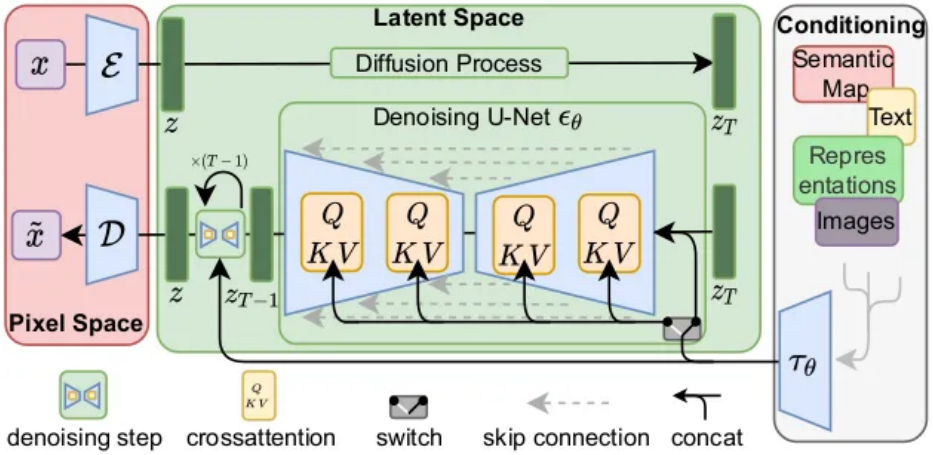
Empirical Approaches

Compression via Denosing



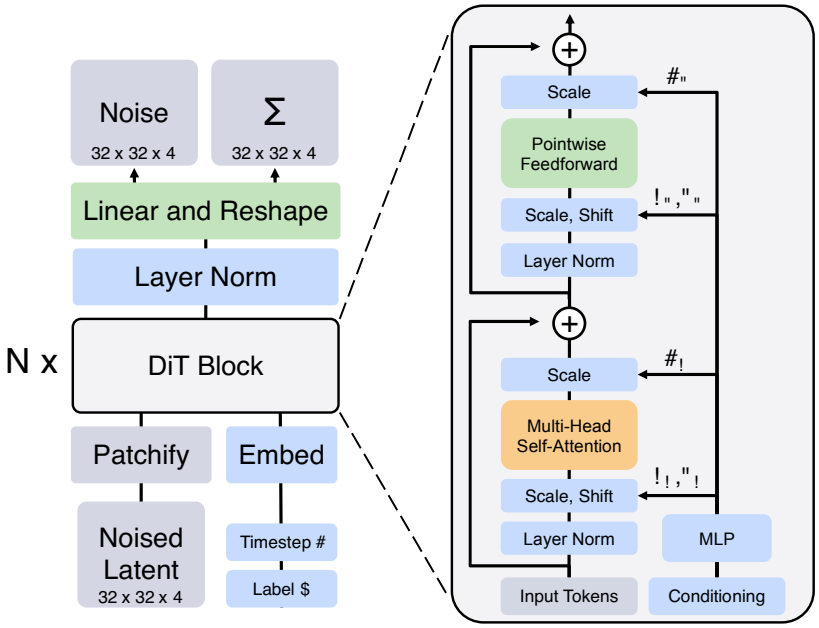
Empirical Approaches

Latent Space Diffusion (U-Net)



Empirical Approaches

Diffusion Transformer (DiT)



Latent Diffusion Transformer

DiT Block with adaLN-Zero