Table Content

C1: The Nature of AI

* Application of AI

Field	**Application**
Education	● Machine Learning models **analyze student performance data** to **personalize lessons**. ● Natural Language Processing (NLP) helps in **auto-grading essays** and **providing feedback**. ● Predictive models **use historical data to forecast outcomes** like **student performance** and **drop-out risks**.
Marketing	● Clustering algorithms (like K-Means) **segment customers based on behavior and preferences**. ● Chatbots use NLP (e.g. GPT or BERT) to **understand and respond to customer queries**. ● Sentiment analysis uses **text classification models to determine user opinions** from social media or reviews.
Finance	● Anomaly detection **flags unusual transaction patterns for fraud**. ● Reinforcement learning is used in algorithms trending to **make decisions based on market analysis**. ● Credit scoring models use regression and classification algorithms on customer data.
Entertainment	● Recommendation systems use collaborative filtering or content-based filtering to **suggest shows or songs**. ● Generative AL models (like GANs or LLMs) **create music, text or video**. ● Computer vision **enhances CGI or enables realistic face-swapping** (deepfakes).
Healthcare	● Convolutional Neural Networks (CNNs) **detect patterns in medical images** (like tumors). ● AI-powered drug discovery uses predictive models to **simulate molecule interactions**. ● Virtual health assistants rely on NLP and decision trees to **give health advice**.
Manufacturing	● Sensor data is analyzed using time-series models to **predict machine failure** (predictive maintenance). ● Computer vision **inspects products using image classification to find defects**. ● RPA bots **imitate human actions** in software to **automate tasks** like inventory tracking.
Food Industry	● Recommendation systems **suggest recipes based on diet**, using

	user profiling and filtering techniques. ● AI **forecasts demand** using time-series forecasting models to **optimize food production**. ● Computer vision **checks freshness or packaging quality**; smart assistants **help in cooking**.
Designing	● Generative Design tools use evolutionary algorithms to **create multiple design options**. ● GANs (Generative Adversarial Networks) **enhance or generate visual content**. ● AI tools **monitor user interaction** and **adapt UX/UI** using reinforcement learning.

Type of System

Systems that think like humans	● Focuses on **cognitive processes** ● The machines **think the way humans do**, using models of human cognitive ● e.g. AI that replicates human problem-solving, like expert systems simulating human decision-making
Systems that act like humans	● Focuses on **behavior** ● It makes machines **mimic human actions** as closely as possible ● e.g. a chatbot that talks like a human, or a humanoid robot that behaves like a person
Systems that think rationally	● Focuses on **logical reasoning** ● AI **thinks in a rational, logical manner, using formal rules of logic and mathematics** ● e.g. the expert systems that use rules and logic to deduce facts, such as Prolog-based AI
Systems that act rationally	● Focuses on **decision-making and actions** ● AI **takes rational actions to achieve the best outcomes**, even if it does not behave like a human ● e.g. self-driving cars optimize routes on AI in financial trading maximizes profits based on data

* Turing Test

Human judge (interrogator)	This person conducts the test by **engaging in a conversation with both a human and a machine**.
Machine	The AI being tested for its ability to **exhibit intelligent behavior**.

Human	To provide a **baseline for comparison with the machine's responses**.

- **Judge communicates with both human and machine** via a test-based interface such as a computer keyboard and screen. So, judges cannot see or hear them directly.
- This ensures that **evaluation is based solely on responses** and not on physical appearance or voice.
- During the test, the **judge asks questions and engages in a conversation** with both the human and the machine.
- Machine's goal is to **respond in a manner that is indistinguishable from the human participant**.
- If the judge **cannot consistently tell which participant is the machine**, the machine is considered to have **passed the Turing Test** (Intelligent).

* Disadvantages of Turing Test

Lack of Contextual Understanding	• Turing Test emphasizes **conversational mimicry rather than true understanding or problem-solving** • Machine might **generate convincing responses without comprehending the context, meaning or implications** of the conversation
Limited Scopes (Multi-Model Intelligence)	• In Turing Test, the **interrogator can only communicate with the machine through language**, without any visual or physical cues • Having **language skills** alone is **not enough to prove that a machine has human-level intelligence**
Ignores Non-Verbal Intelligence	• Turing Test primarily focuses on **linguistic and conversational intelligence** • It does **not account for other forms of intelligence** such as problem-solving, creativity or emotional intelligence

* Chinese Room

- The Chinese room argument is a thought experiment designed to **challenge the notion that computers can possess genuine understanding or consciousness, despite potentially exhibiting intelligent behavior**.
- Searle imagines himself as an English speaker who is placed inside a room with no understanding of the Chinese language.
- There is a set of boxes filled with Chinese characters and a manual written in English that provides instructions on how to manipulate these characters.

- Input: Chinese speaker outside the room slips written Chinese characters under the door.
- Manipulation: Searle selects the appropriate responses based on the input characters and sends them back out without understanding its meaning.
- Outcome: From the perspective of an outside observer, it looks like there is a person inside the room who understands Chinese as the responses are coherent and contextually appropriate.
- This argument indicates that any computer or him **does not have actual understanding although it or he can produce responses that seem intelligent** during the Chinese Room scenario.

<u>Turing Test Application</u>

Captcha	• To **prevent automated systems from being used to abuse the site** • If any software is able to read the distorted image accurately, so any system able to do so is likely to be human.

C2: Problem Definition and Problem Solving

Problem-Solving Concept

Step 1: **Goal Formulation**	**Abstractions**: What is the scope? **Optimal solution**: What is the best solution? **Goal**: What is the outcome?
Step 2: **Problem Formulation**	Process of deciding what actions and states to consider **Initial state** **State space** **Path** **Path cost** **Successor function** **Goal test** **Step cost**
Step 3: **Search-solution-execution**	**Search**: Process of looking for the best sequence of path **Solution**: A search algorithm takes a problem as input and returns a solution in the form of an action sequence **Execution**: Once a solution is found, the actions it recommends can be carried out

Measuring Problem-Solving Performance

Completeness	Is the algorithm guaranteed to find a solution when there is one?
Optimality	Does the strategy find the optimal solution?
Time complexity	How long does it take to find a solution?
Space complexity	How much memory is needed to perform the search?

C3: Uninformed Search

Breadth-First Search

Definition	All the nodes are expanded at a given depth in the search tree before any nodes at the next level are expanded.
Algorithm	1. Begin with the root node. 2. Examine all of the nodes in each level before moving on to the next level. 3. Repeat the process and work downward from left to right until a solution is found. 4. Return Fail if there is no solution.

Depth-First Search

Definition	Always expands the deepest node in the current fringe of the search tree.
Algorithm	● Nodes leading from dead ends normally will be discarded from memory. ● Then the search will back up to the next shallowest node that still has unexplored successors. ● Implemented by calling tree search using LIFO (Last-In-First-Out) strategy.

Measuring Problem-Solving Performance

* This is just a sample, the results may vary based on different scenarios.

Criteria	Breadth-First Search (BFS)	Depth-First Search (DFS)
Completeness	**Complete** - BFS will **find a solution if one exists, and it explores all possible paths level by level**.	**Not always complete** - DFS may **get stuck in infinite loops or miss certain paths**, depending on the specific implementation and problem.
Optimality	**Optimal** - BFS **guarantees the shortest path in terms of the number of edges or steps taken**.	**Not guaranteed to be optimal** - DFS may **find a solution faster**, but it **doesn't necessarily find the shortest path**.
Time Complexity	The time complexity of BFS is O(V+E) when Adjacency List is used and O(V^2) when Adjacency	The Time complexity of DFS is also O(V+E) when Adjacency List is used and O(V^2) where Adjacency

	Matrix is used, where V stands for vertices and E stands for edges.	Matrix is used, where V stands for vertices and E stands for edges.
Space Complexity	**Requires more memory** as it needs to **store all nodes at the current level**.	**Requires less memory** as it only needs to **store the path from the root to the current node**. Depth of recursion is limited.

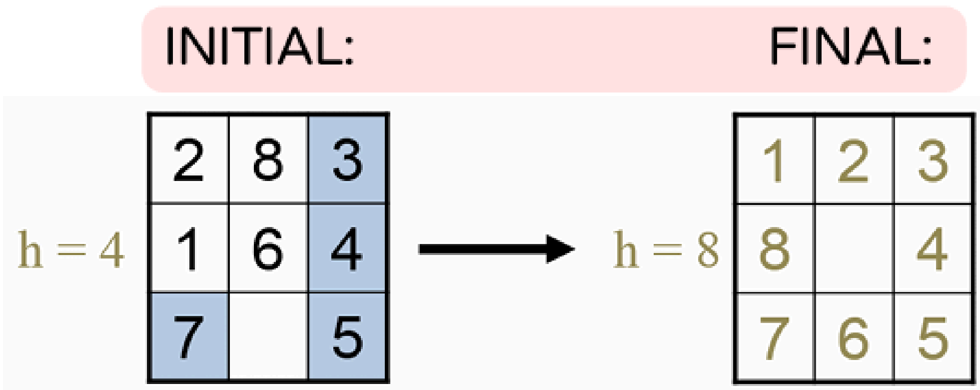
C4: Informed Search

Heuristic Function

- The heuristic function, h(n) indicates how "close" a state n is to the goal.

EXAMPLE

Let the heuristic function, h(n), is given as follows:
h(n) = number of tiles at the right place.
* h(n) determines the heuristic cost of a state



Simple Hill Climbing

Algorithm	1. Set initial state to current 2. Loop on the following until goal is found or no more operators available ● Select an operator and apply it to create a new state ● Evaluate new state ● If new state is better than current state, perform operator making new state the current state 3. Once loop is exited, either we have found the goal or return fail
Limitations	● It is less combinatorially explosive as it searches locally rather than globally ● Possibly very inefficient and ineffective ● It will be stuck when facing a dead end where all the child nodes are worse than the parent node.

Steepest Ascend Hill Climbing

Algorithm	1. Set initial state to current.
	2. Loop on the following until goal is found or a complete iteration occurs without change to current state
	    ● Generate all successor states to current state
	    ● Evaluate all successor states using heuristic
	    ● Select the successor state that yields the highest heuristic value and perform that operator

Limitation	● It will be stuck when facing a dead end (all heuristic costs of child nodes are lower or same with the current state)

Limitations of Hill Climbing

Foothills	Local high points (local maximum):
Plateau	Flat area (neighboring states have equal or very similar values)
Ridges	Narrow rising path (Can't find correct path due to limited search)

Local Heuristic

Characteristics	● Less combinatorially explosive (less complex) ● Possibly very inefficient and ineffective
Concept	If the block rests on the right place, add 1. Else, minus 1.

Global Heuristic

Concept	1. For each block that has the correct support structure, +1 for every block in the support structure. 2. For each block that has an incorrect support structure, -1 for each block in each block in the existing structure.

Best First Search

Characteristics	● More flexible ● Use priority queue ● Heuristic is used (to estimate the promising state/path)
Algorithm	1. Place the starting node into the OPEN list.

	2. If the OPEN list is empty, stop and return failure. 3. Remove the node n, from the OPEN list which has the lowest value of h(n) (depending on the designed heuristic function), and place it in the CLOSED list. 4. Expand the node n, and generate the successors of node n. 5. Check each successor of node n, and find whether any node is a goal node or not. If any successor node is a goal node, then return success and terminate the search, else proceed to Step 6. 6. For each successor node, the algorithm checks for the value of h(n), and then checks if the node has been in either the OPEN or CLOSED list. If the node has not been in both lists, then add it to the OPEN list. 7. Return to Step 2.

Differences between Simple Ascend Hill-Climbing & Best-First Search

Simple Ascend Hill-Climbing	Best-First Search
One move is selected and **all others are rejected**, which will not be reconsidered.	One move is selected, but **others are still kept around** so that they can be **revisited later**.
Will **quit if there is no better successor / children state than the current state**.	Will **try on other nodes which initially was less promising**

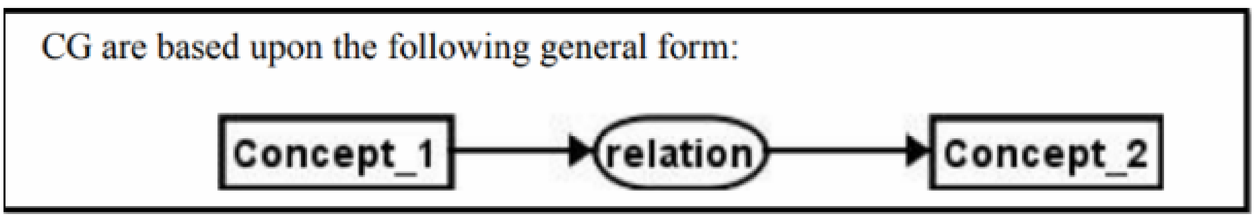
C5: Knowledge Representation

* Semantic Networks

Advantages	Disadvantages
Easy to visualize and understand	No standards about node and arc values
Related knowledge is easily categorized	This not describes the attributes
The knowledge engineer can arbitrarily defined the relationships 知识工程师可以任意定义以下关系	

Conceptual Graph

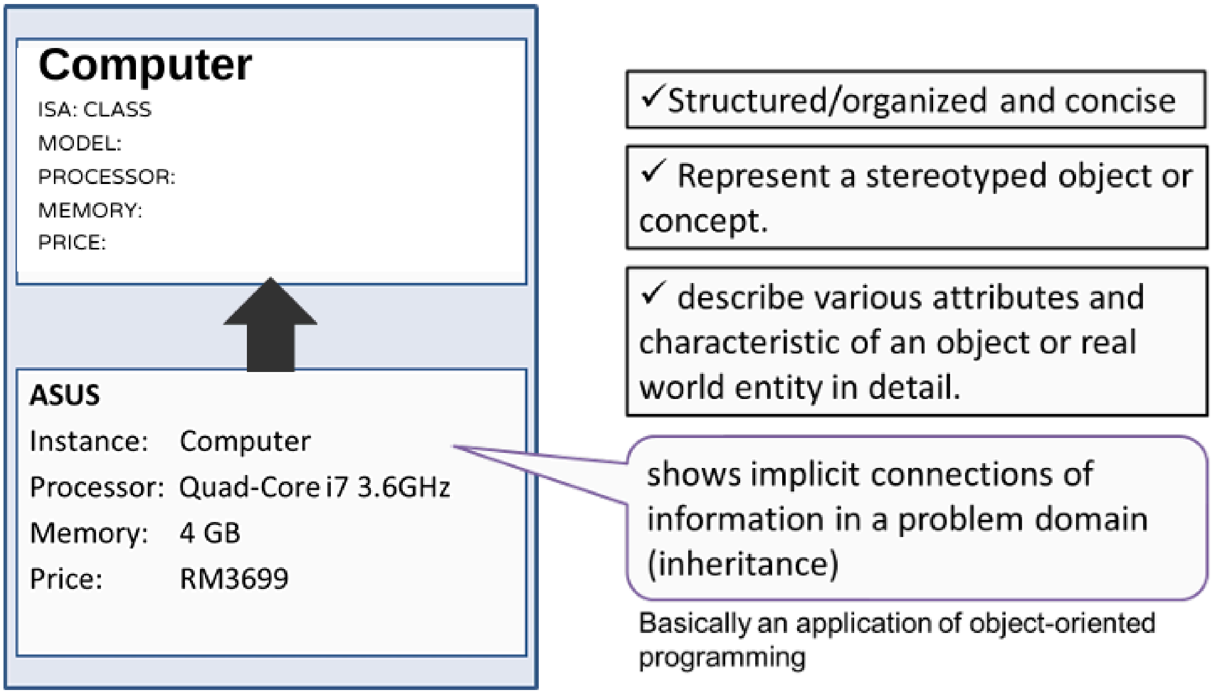
- The nodes of the graph are either concepts or conceptual relations
- Do not use labeled arcs
- Conceptual relations nodes represent relations between concepts



AND/OR Graph

- A.k.a. hypergraph / inference network
- Suitable for rule-based system
- Graphical representation of reduction of problems (or goals) to conjunctions and disjunctions of subproblems (or subgoals) in Hierarchical Structure

* Frames



Concept	• Data structures used to **divide knowledge into substructures** by representing "stereotyped situations" • Structured record **describes an entity in the world**, such as an object or event, by **using a collection of attributes and their values** • These attributes often referred to as "slots", and the values they hold are called "facets"

Advantages	• Expressive power
	  ○ Easy to understand
	  ○ Represent stereotyped object
	  ○ More detail than semantic network
	• Flexible
	  ○ Easy to set up slots / new properties
	  ○ Easily create specialized procedures
	  ○ Allow default data
	  ○ Easily detect missing value
	• Show inheritance
	  ○ Show hierarchical structure
	• Show constraints
	  ○ Allow constraints to be set for value / facets

Disadvantages	• Difficult
	  ○ Difficult to program, especially making inference
	• Limited
	  ○ Not suitable to describe sequence of events, action, etc
	  ○ Not description on syntax/semantic of a sentence, etc "bank"
	• Incomplete

	○ Individual frame cannot give full picture ○ Details may be omitted during representation ○ Cannot be quantified, e.g. "all", "some"

C6: Natural Language Understanding

* NLP, NLU & NLG

NLP (Natural Language Processing)	● The broad field of AI that focuses on enabling machines to **understand, interpret and generate human language** ● Includes **understanding and generation tasks** ● e.g. translation, sentiment analysis, summarization, speech recognition
NLU (Natural Language Understanding)	● A subfield of NLP focused on **making sense of human language input** ● Goal: **understand meaning, intent and context** ● e.g. semantic analysis, syntactic parsing, named entity recognition
NLG (Natural Language Generation)	● A subfield of NLP focused on **generating human-like language from structured data or text** ● Goal: **convert machine-readable information into readable sentences** ● e.g. ChatGPT, AI writing tools, weather report generation, auto-captioning

* Natural Language Processing (NLP)

NLP Application	
Word-sense disambiguation	● **Identifying the correct meaning of a word based on context** ● NLP helps in **accurate translation, search and understanding of meaning** ● Context examples: Bank, Goal
Named entity recognition	● **Identifying and classifying proper nouns in text into categories** like names, organizations, locations, brands ● NLP helps for **information extraction, question answering** and **chatbot understanding** ● Context examples: Canon, Apple
Information retrieval	● **Finding relevant documents or data based on query** ● NLP uses query expansion, ranking algorithms and language models to **improve search results** ● Example: Search engine (Google or Bing)

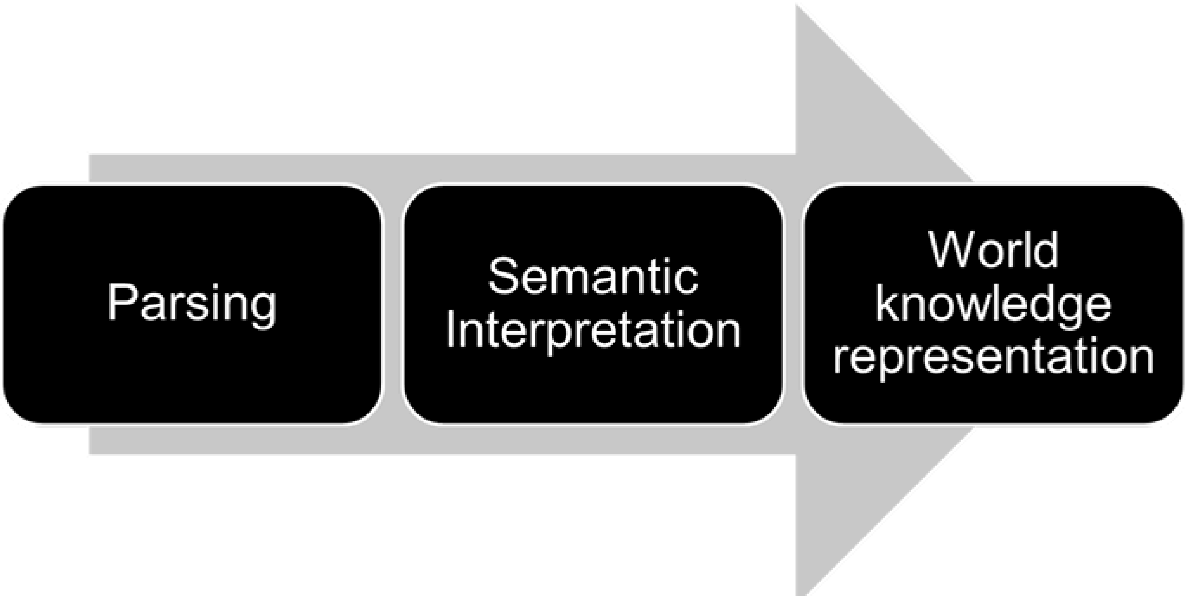
Summarization	• **Automatically generating a concise version of a long text** while preserving key information • e.g. QuillBot's Summarizer simplifies or condenses text using NLP • e.g. Summarizer.org extracts important sentences from articles
Machine Translation	• **Translating text from one language to another automatically** • NLP applies sequence-to-sequence models to preserve meaning, grammar and context • Examples: Google Translate, Microsoft Translator

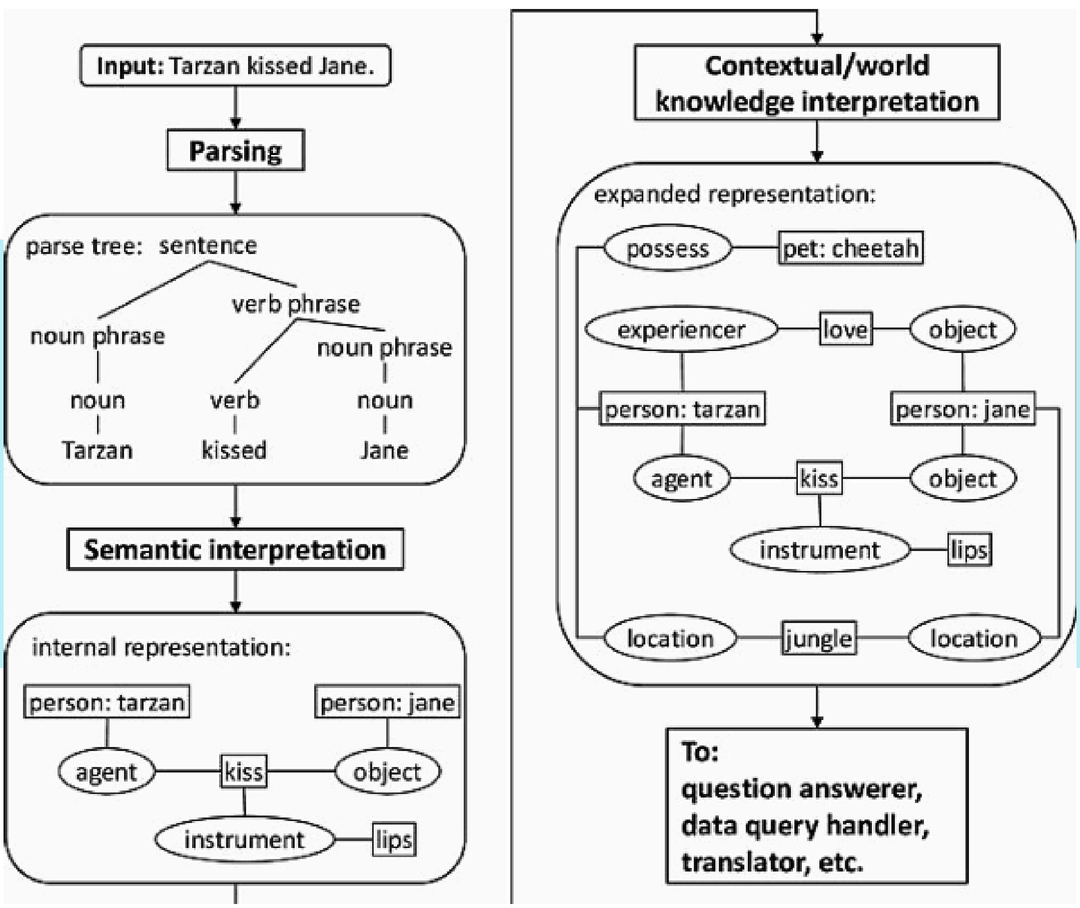
* NLU Challenge

Transmission of words	• **Spoken or typed words may be misspelled, misheard or grammatically incorrect** • NLU systems must **handle noise, ambiguity, slang or incorrect syntax** while still extracting meaning
Inferences about speaker's goals	• **Understanding the intended meaning behind what is said**, not just the literal words 理解话语背后的含义，而不仅仅是字面意思 • NLU require **intent detection** and **understanding indirect speech acts** 无语言障碍要求检测意图并理解间接言语行为
Knowledge	• Comprehending language often **requires background or world knowledge** • AI **lacks common sense reasoning and massive real-world knowledge** like humans
Assumptions	• **Speakers often leave out information they assume the listener knows** • NLU requires coreference resolution and shared context inference, which AI often struggles with 需要解决核心推理和共享语境推理问题，而人工智能在这方面往往很吃力
Context of the interactions	• **Meaning changes based on time, location, prior conversation, or even tone** • NLU needs to integrate previous dialogue, environment, or emotional tone, which is complex

Stages of Language Analysis

Translate the original sentence into an internal representation of its meaning by the following stages:





Parsing	● **Analyze the syntactic structure of sentences** ● **Identifying the major relations** such as subject-verb, verb-object, noun-modifier ● Often represented as parse tree ● Employs knowledge of language syntax, morphology and some semantics
Semantic Interpretation	● **Representation of the meaning** ● Use semantic network, conceptual graph, conceptual dependencies, frames, etc ● **Uses knowledge about the meaning of words and linguistic** ● **Perform consistency checks and include constraints** ● It can solve canonical form of sentences (two different sentences with the same meaning)
World Knowledge Representation	● Methods and structures used to **model and store information about the real world** that can be understood and utilized by AI systems ● This **encompasses the encoding of entities, concepts, relationships and facts about the world** in a way that facilitates reasoning, understanding, and intelligent behavior by machines

* Symbolic Analysis in NLP

Morphology	● Components such as **prefixes** (un-, non-, anti-) and **suffixes** (-ing, -ly) ● **Meaning of root words may change** ● Morphological analysis is the first phase of natural language processing (NLP) that examines the internal structure of words. It involves breaking words down into their smallest meaning-bearing units called morphemes.
Prosody	● **Rhythm and intonation of language** ● Relate to **emotion**
Phonology	● **Combination of sounds to form language** ● **Pronunciation**
Syntax	● Rules for **combining words into legal phrases and sentences** ● e.g. grammar
Semantics	● The **meaning of words, phrases and sentences**
Pragmatics	● The **study of the ways in which language is used and its effects on the listener** ● Through **experience**

World knowledge	**Knowledge of the physical world, human interaction, the role of goals and intentions in communication** - Ontology 本体论

* Syntactic VS Semantic Ambiguity

Syntactic Ambiguity	Semantic Ambiguity
The same sequence of words is **interpreted as having different syntactic structures**.	The structure remains the same, but the **individual words are interpreted differently**.
e.g. "They are hunting dogs"	e.g. "Meet me at the bank"

C7: Machine Learning (Supervised Learning)

Artificial Intelligence	Applications that mimic human behavior
Machine Learning	• Ability to learn and make decision without being explicitly programmed • Definition: A set of methods that can **automatically detect patterns in data**, and then **use the uncovered patterns to predict future data**, or to perform other kinds of **decision making under uncertainty**.
Neural network	Backbone to Deep Learning: mimic human brains through a set of algorithms
Deep learning	"Deep" refer to depth of layers in a Neural Network

* Supervised Learning VS Unsupervised Learning

Aspect	Supervised Learning	Unsupervised Learning
Definition	Supervised learning involves **training a model using labeled data**, where the input data is paired with corresponding correct output or target values. The goal is to **learn a mapping from inputs to outputs**.	Unsupervised learning involves **training a model on unlabeled data**, where the algorithm tries to **find patterns or structure within the data without specific target values**.
Learning Process	The model **learns from examples provided in the form of input-output pairs**. It learns to **generalize and make predictions on new, unseen data**.	The model **learns to identify patterns, clusters, or relationships in the data without being explicitly given the correct answers**.
Goal	**Learn a mapping or relationship between inputs and outputs**, enabling the model to predict the output for new, unseen inputs accurately.	**Discover hidden patterns, groupings, or structure within the data**, often for purposes like segmentation or anomaly detection.
Examples	Classification and regression are common tasks in supervised learning. **Image classification, spam email detection and predicting stock prices**.	Clustering, dimensionality reduction and anomaly detection are typical tasks in unsupervised learning. **Customer segmentation and topic modeling**.
Training	Labeled training data with input-output	Unlabeled or partially labeled data is

Data	pairs is required for supervised learning.	used for unsupervised learning.
Evaluation	Models are evaluated using metrics like **accuracy, precision, recall, and F1-score**, which compare predicted outputs to actual target values.	Evaluation can be more **challenging** in unsupervised learning. It might involve **assessing the quality of patterns, clusters**, or other structures discovered in the data.
Human Intervention	**Requires human effort to label the training data with correct output values**.	Generally **requires less human effort for data labeling**, but might involve human interpretation of results for validation and understanding.
Use Cases	Supervised learning is used for tasks where the correct output is known, and the model needs to generalize from the training data to make predictions.	Unsupervised learning is used for tasks where the goal is to explore and uncover insights from the data, often in cases where labeled data is scarce or unavailable.
Example Algorithms	Decision trees, neural networks, support vector machines (SVM), and linear regression.	K-means clustering, hierarchical clustering, and principal component analysis (PCA).

Accuracy, Precision and Recall

n=165	Predicted: NO	Predicted: YES
Actual: NO	True Negative 50	False Positive 10
Actual: YES	False Negative 5	True Positive 100

Accuracy	$\frac{(TP+TN)}{Total} = \frac{(100+50)}{165} = 0.91$

Precision	$\frac{TP}{FP+TP} = \frac{100}{10+100} = 0.91$
Recall	$\frac{TP}{FN+TP} = \frac{100}{5+100} = 0.95$

C8: Machine Learning (Unsupervised Learning)

* Application of Unsupervised Learning

Search Engine	• Application: **Topic modeling and clustering of web pages or queries** • How it works: **Groups similar documents or user queries** using techniques like K-Means • Benefit: **Improves search relevance, auto-suggestions and query categorization** without needing labeled data.
Business and Marketing	• Application: **Customer segmentation** • How it works: Unsupervised algorithms (e.g. K-Means) **group customers based on behavior, purchase history or demographics** • Benefit: **Helps businesses create targeted marketing strategies and personalized offers**.
Image Segmentation	• Application: **Separating different parts or objects in an image** • How it works: Algorithms like clustering (e.g. K-Means) **group pixels based on color, intensity or texture to segment the image into meaningful regions** • Benefit: Used in object detection, background removal and preprocessing in computer vision
Medical Imaging	• Application: **Detecting abnormal patterns or segmenting organs / tissues** • How it works: Clustering and dimensionality reduction (PCA, Autoencoders) **identify hidden patterns or group similar image features** in scans (MRI, CT)

* Clustering Algorithm Evaluation

- Why clustering is hard to evaluate:
    - **We do not know the correct clusters.**
    - **Cluster centers are arbitrary. (unclear / randomly)**

Intra-cluster cohesion (compactness)	• **Cohesion** measures **how near the data points in a cluster are to the cluster centroid**. • Sum of squared error (SSE) is a commonly used measure. • Goal: **minimize the distance between points and their cluster centroid.** • Example metrics: ○ Within-Cluster Sum of Squares (WCSS)

<table>
<tr><td></td><td><li style="list-style:none">
Silhouette Score
Dunn Index</td></tr>
<tr><td>Inter-cluster separation (isolation)</td><td>Separation means that different cluster centroids should be far away from one another.
Goal: Maximize the distance between cluster centroids or between the nearest points in different clusters.
Example metrics:
Davies-Bouldin Index
Silhouette Score
Dunn Index</td></tr>
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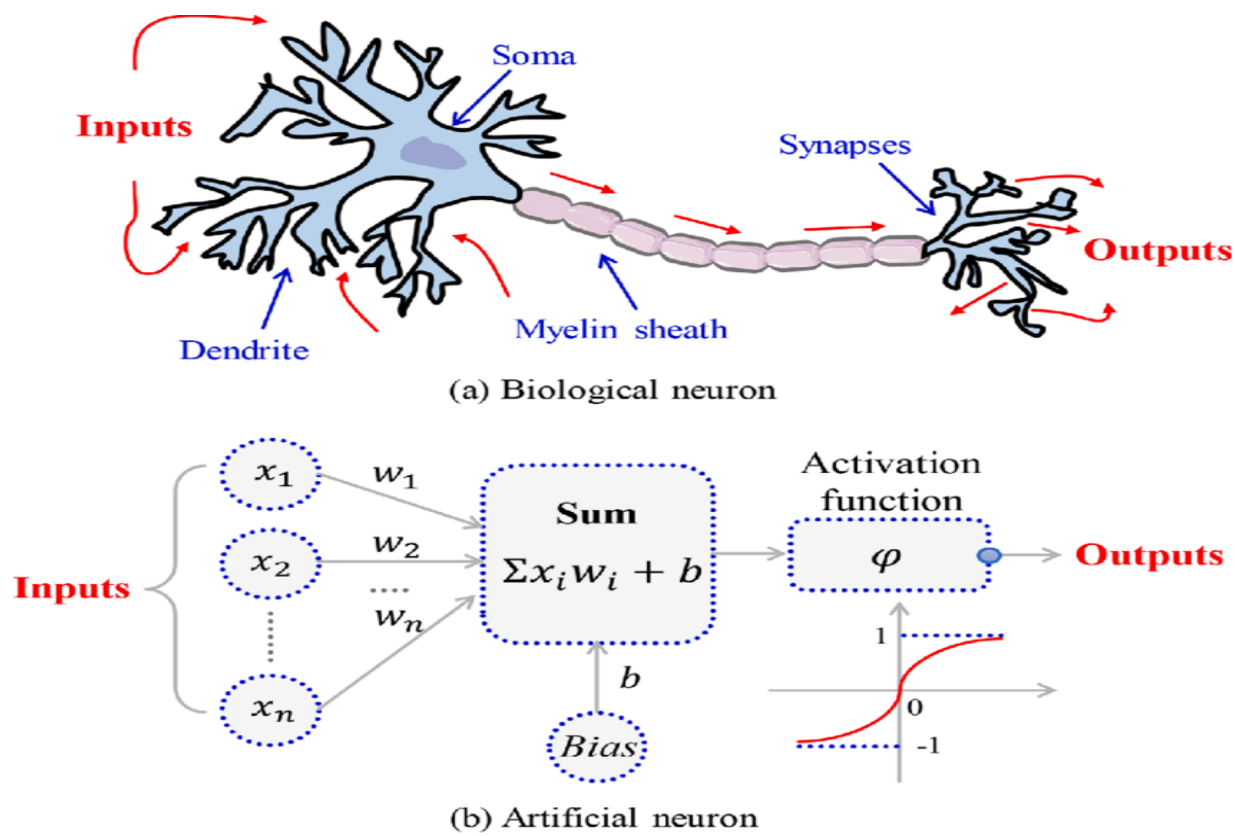
C9: Artificial Neural Network

Brain



(a) Biological neuron

(b) Artificial neuron

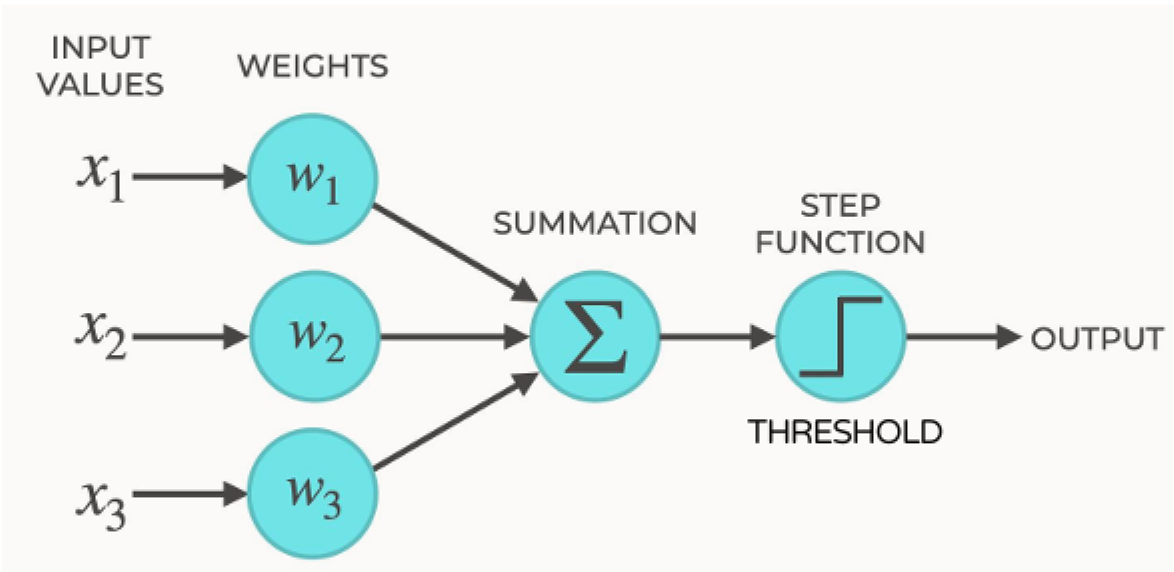
Soma	The basic cell body
Dendrite	Receive signals from axon
Axon	Propagate signals from one neuron to another
Synapse	Release chemical substance to cause the change in the electrical potential of the cell body

Analogy BNN VS ANN

BNN	ANN	Functions
Soma	Neuron	Information processing

Dendrite	Input	Receive data
Axon	Output	Transmit data to another neuron
Synapse	Weight	To express the strength or the importance of neuron input

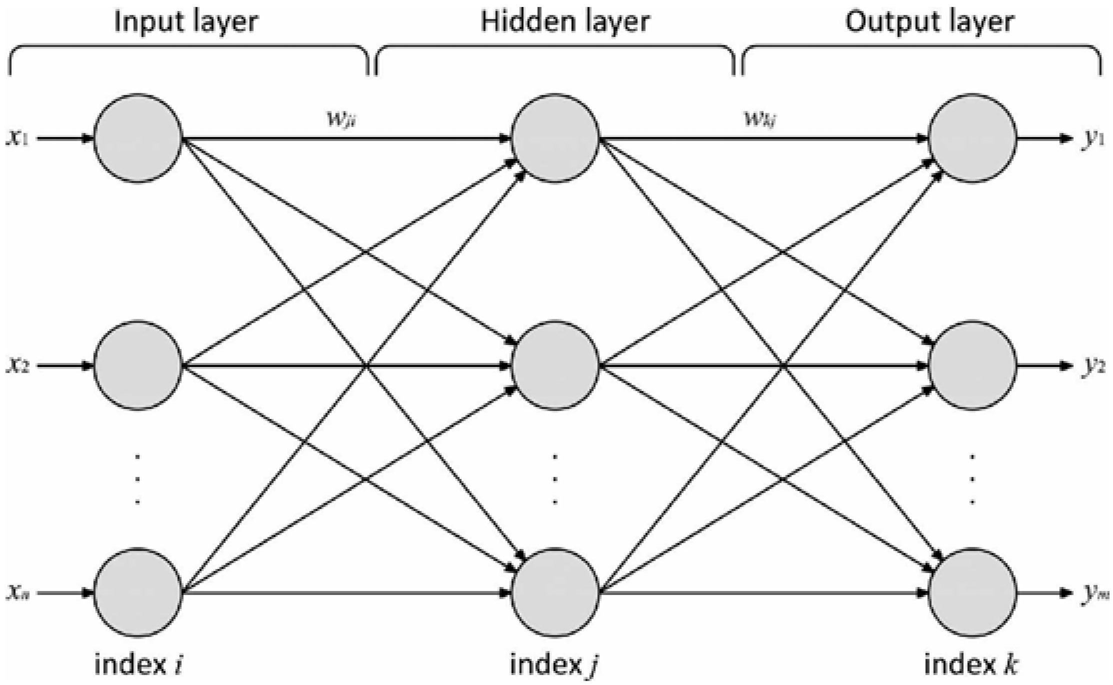
Perception



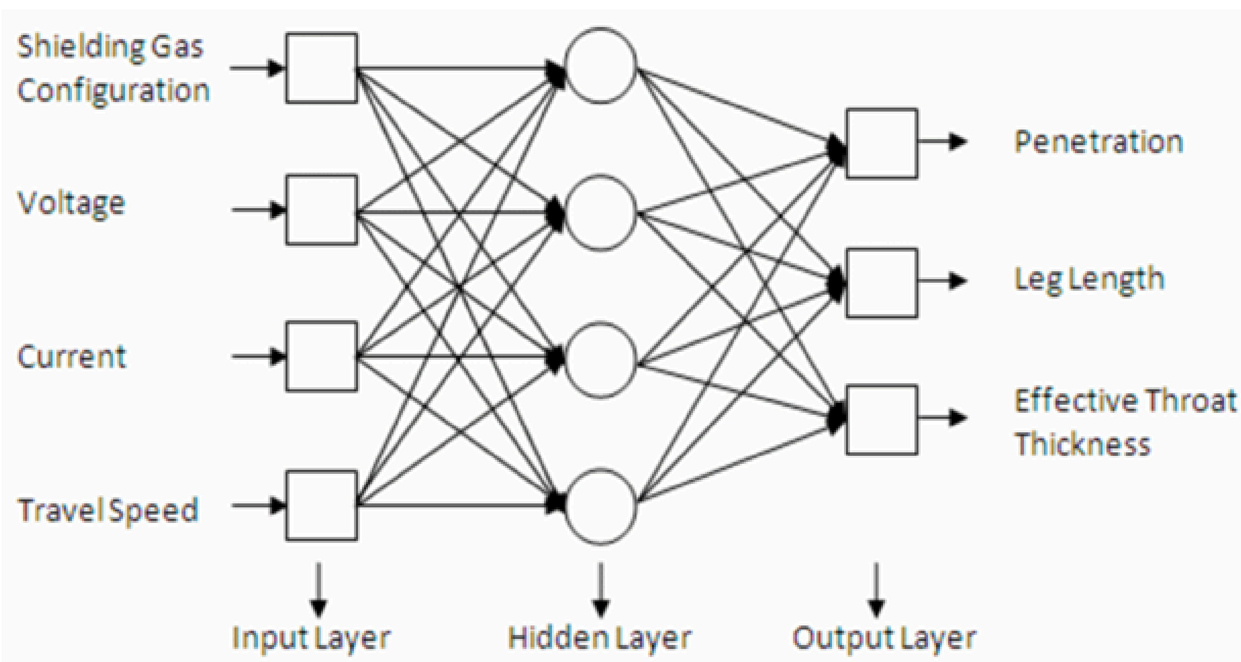
3 Layers in Neural Network Model	
Input Layer	• Role: **Receives raw data** • Function: **Passes data to the hidden layer** • Example: For an image, the input layer would have neurons for each pixel value
Hidden Layer	• Function: **Performs computations and feature transformation** • Uses **weights** and **biases** • **Learn patterns** and **representations** from the data
Output Layer	• Function: **Produces the final result (prediction or classification)** • Number of neurons = number of output classes or values

Multilayer Perceptron

- A feedforward neural network with one or more hidden (middle) layers.
- The network consists of an input layer of source neurons, at least one middle or hidden layer of computational neurons, and an output layer of computational neurons.
- The input signals are propagated in a forward direction on a layer-by-layer basis.



Input layer
Hidden layer
Output layer
w_{ji}
w_{kj}
x_1
x_2
x_n
y_1
y_2
y_m
index i
index j
index k



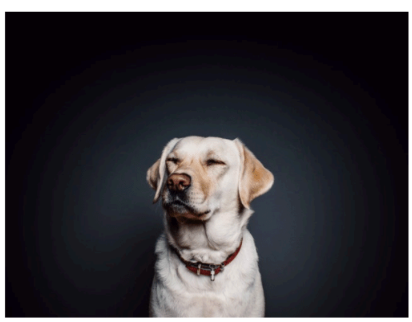
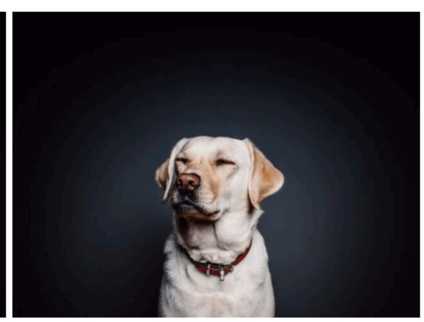
Shielding Gas Configuration
Voltage
Current
Travel Speed
Penetration
Leg Length
Effective Throat Thickness
Input Layer
Hidden Layer
Output Layer

C10: Image Processing and Computer Vision

Image Processing

Image Processing	- Deals with **manipulating and enhancing images to improve their visual quality or extract useful information** - Techniques involved: **altering the appearance** of image by adjusting its brightness, contrast, color balance and other attributes **Remove noise, sharpen images, perform image compression, and apply various filters** - Goal: **Improve the visual quality of images** or make them more suitable for a specific application

Examples of Image Processing	
Image Denoising	

Image Sharpening	
Color Correction	
Image Compression	 Original (28KB)  Lossy Compression (14KB, 50%)

* Properties of Images

Spatial resolution	• Width pixels / width cm and height pixels / height cm • **The number of independent pixels values per inch**

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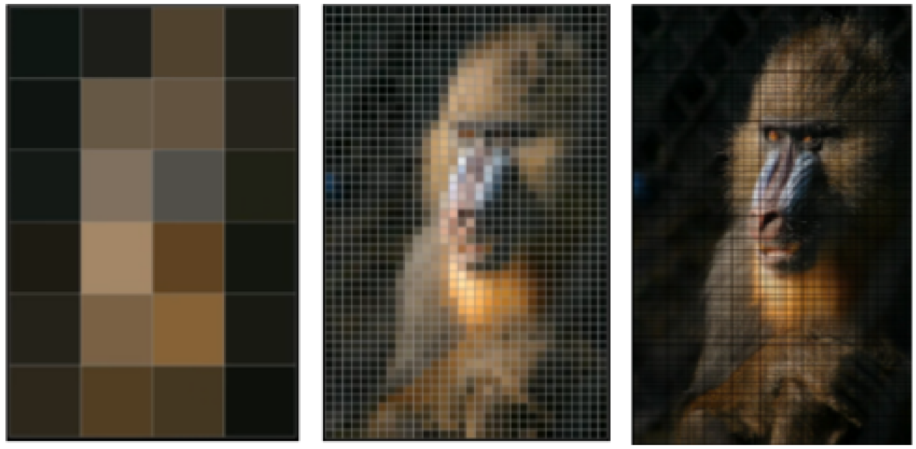
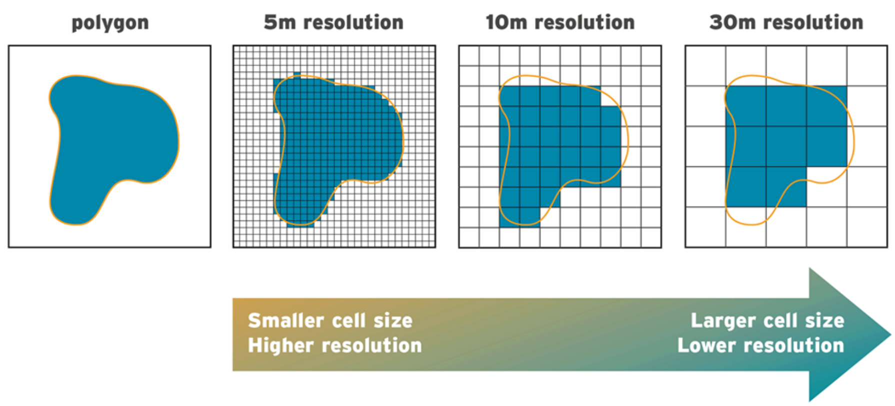

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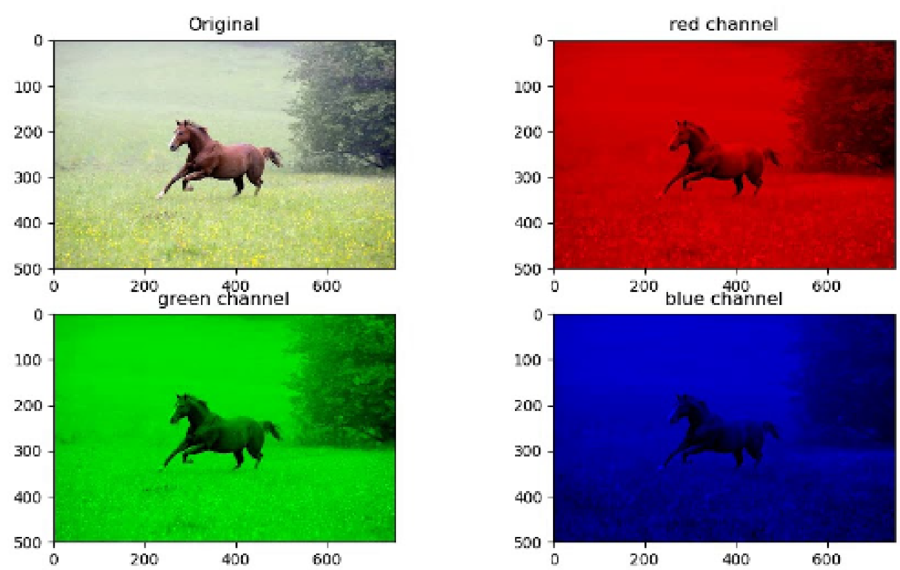
<tr>
<td>Number of channels</td>
<td>

- Number of channels refers to the **number of separate and distinct components or bands of information that make up an image**



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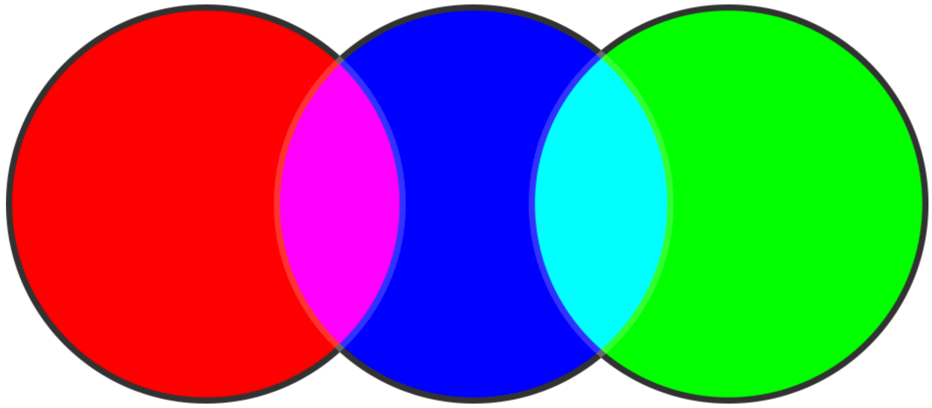
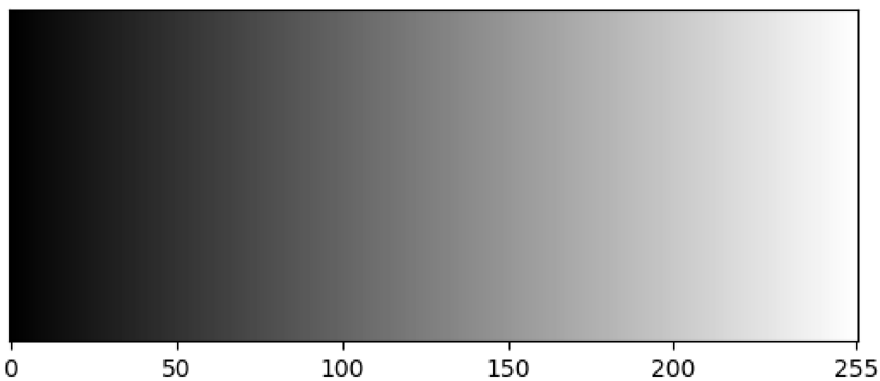
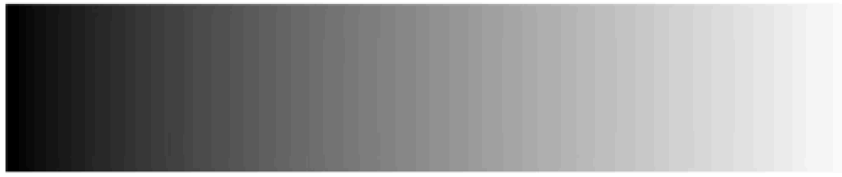
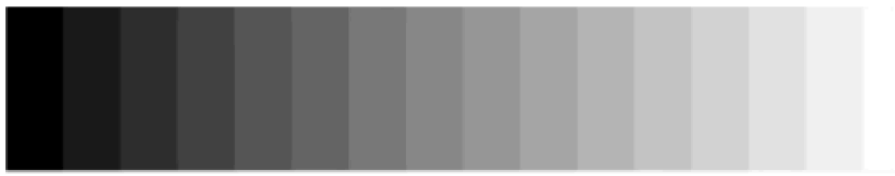
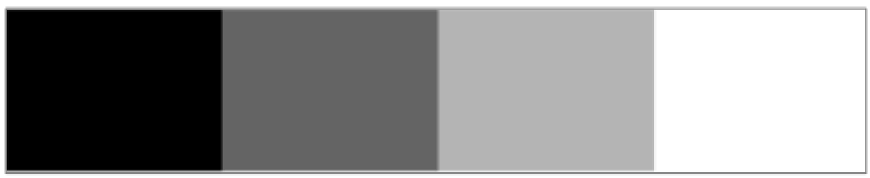
	
Intensity resolution	• Ability of an imaging system to **distinguish between different levels of brightness or intensity in an image** • Determining the **image's color depth** and the **range of colors and shades it can display** 



128 gray levels



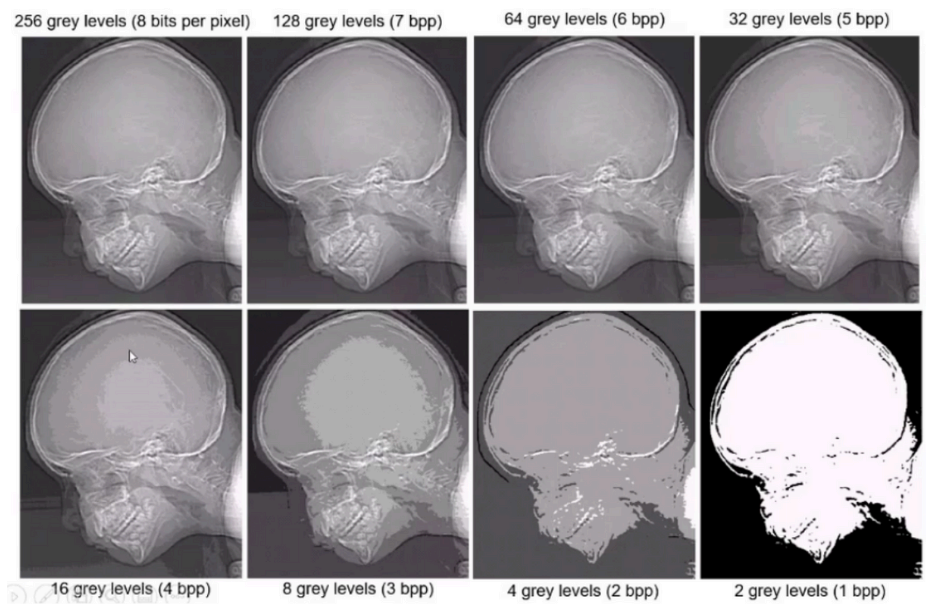
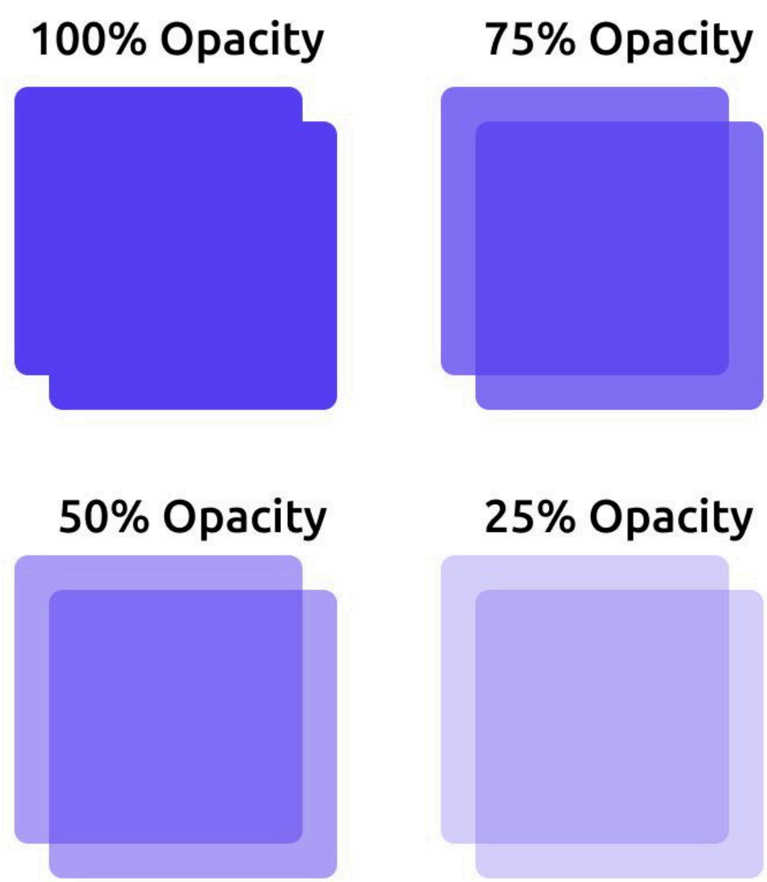
16 gray levels



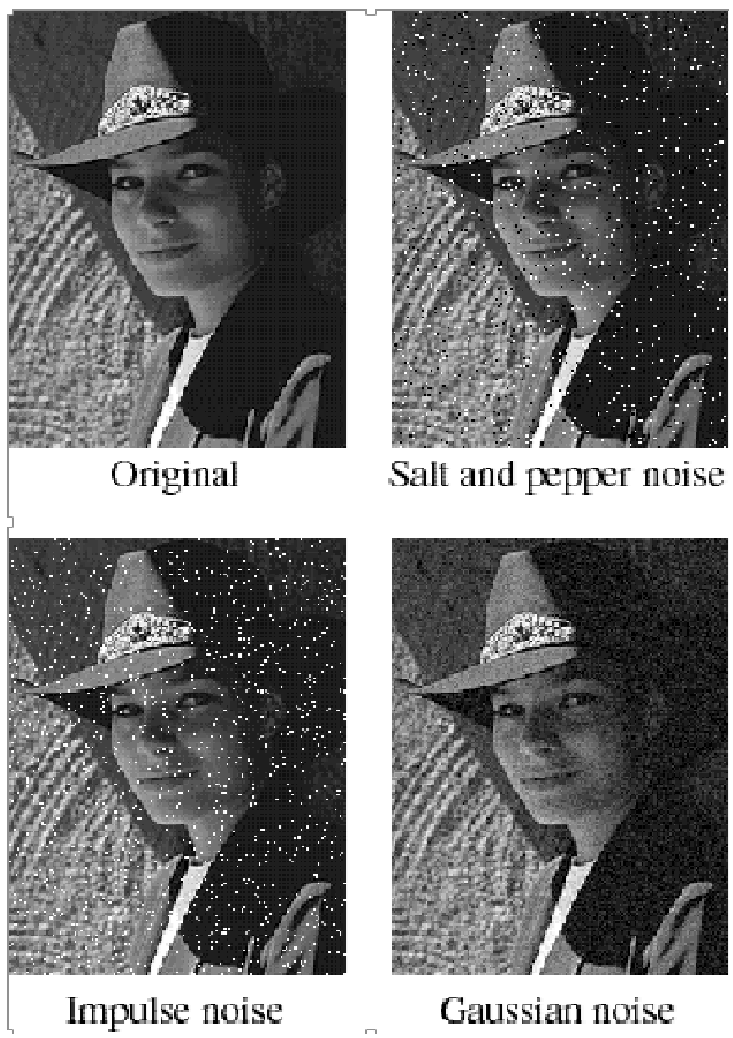
4 gray levels

128 gray levels

4 gray levels

	
Opacity	● **Degree to which a material prevents light from passing through it** 

Preprocessing - Image Noise Remover

Image Noise Remover	Remove unwanted signal in the image
Importance	● To **recover from the image noise** that might caused by different intrinsic (e.g. sensor) and extrinsic (e.g. environment) conditions which are often not possible to avoid in practical situations ● To ensure the **smoothness and the best performance** of the later processing steps ● To **eliminate unintended information** during feature extraction
Common types of noise	● Salt and pepper noise: contains random occurrences of black and white pixels ● Impulse noise: contains random occurrences of white pixels ● Gaussian noise: variations in intensity drawn from a Gaussian normal distribution 

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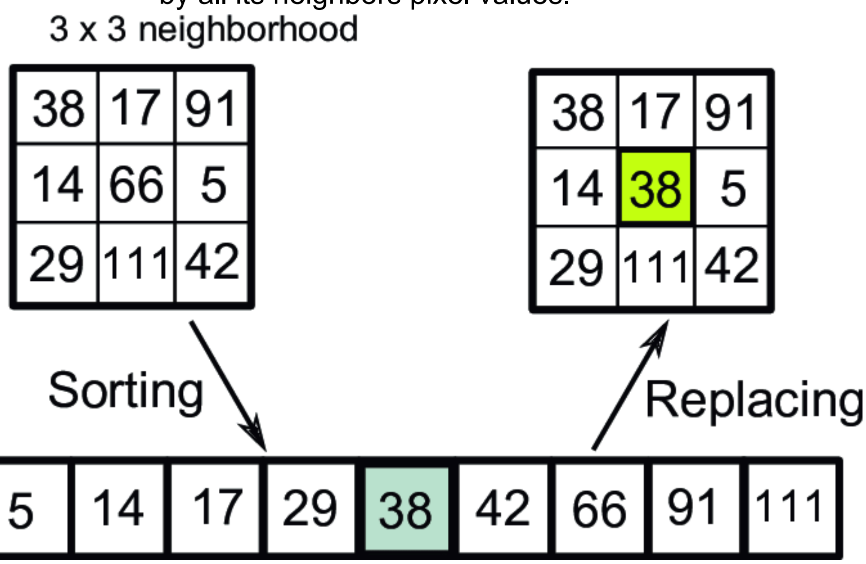
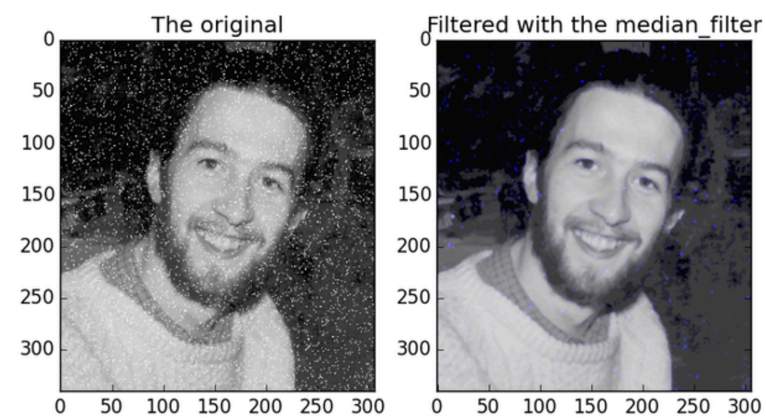
<tr>
<td>Method of recovery</td>
<td>

- Gaussian Filtering: Filter with Gaussian Filter with different standard deviation value

p = 10% σ = 1 pixel σ = 2 pixels σ = 5 pixels

- Median Filtering:
    - **Operates over a window by selecting the median intensity in the window**
    - Determines the value of a central pixel (in a fixed kernel size which 3X3 is often used) and supported by all its neighbors pixel values.





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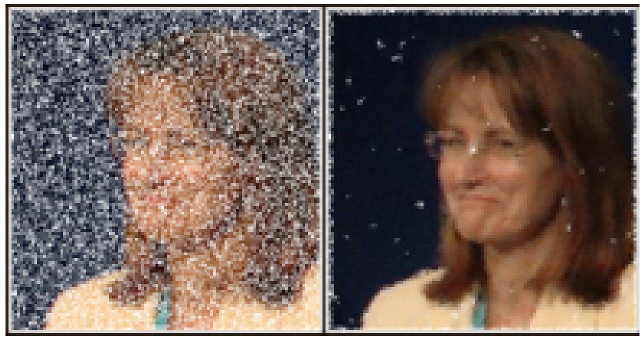
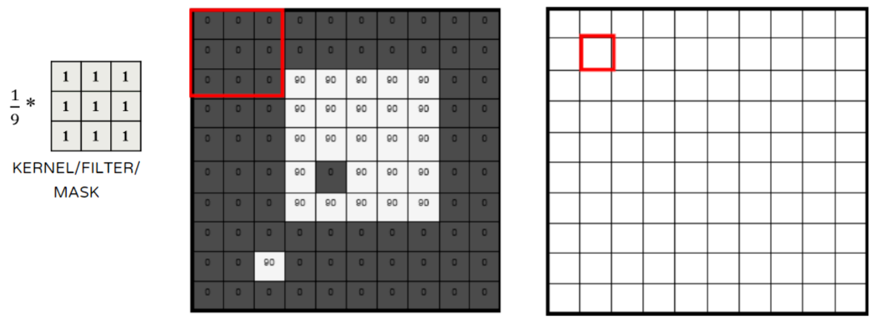
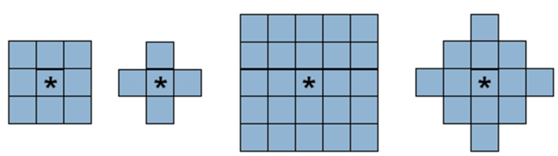
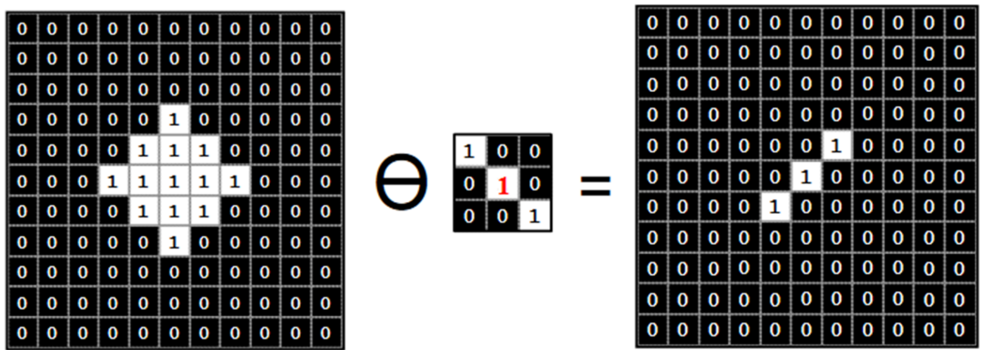
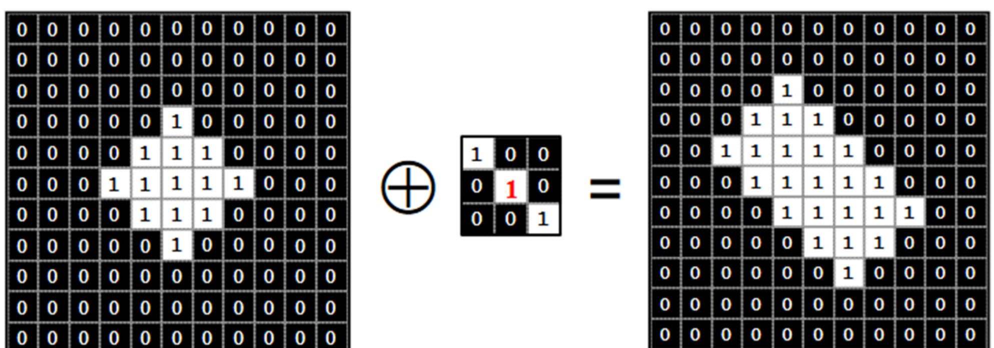
	 ● Average Filter: Replacing each pixel in an image with the average value of its neighboring pixels 

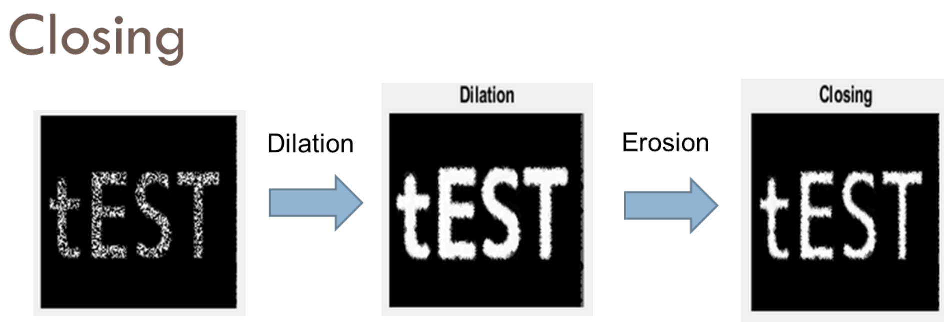
Preprocessing - Morphological Operation

Morphological Operation	● To simplify the objects by ○ Filling in small holes ○ Eliminating small protrusions from their boundaries ● Boundary pixels ○ Object pixels that have background neighbors ● Support by structuring element 
Erosion	● Elimination of boundary pixels from objects in binary images ● Making objects smaller, also called shrinking

	$R' = R \Theta A$  (a) (b) (c)
Dilation	• Each background pixel that has a neighbor in the object is relabeled as an object pixel • Making object bigger, also called growing $R' = R \oplus A$  (a) (b) (c)
Opening	• A single erosion followed by a single dilation by the same operator **Opening** 

<table>
<tr>
<td>Closing</td>
<td>

- A single dilation followed by a single erosion by the same operator



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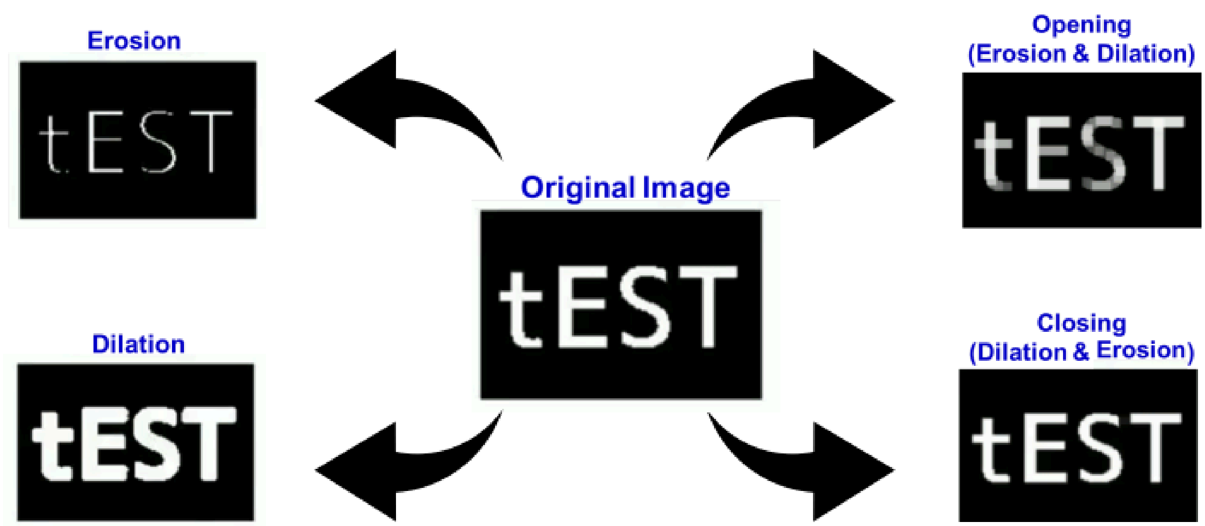


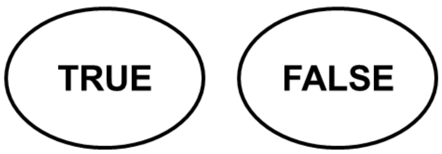
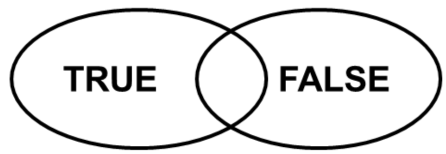
Challenges of Image Processing

- The ability to **extract pertinent information from a background of irrelevant details**
- The **capability to learn from examples** and to generalize this knowledge so that it will apply in new and different circumstances
- Ability to **make inferences from incomplete information**

C12: Uncertainty in Expert System

Classic Logic VS Uncertainty

Classic Logic	**Uncertainty**

• Permits only exact reasoning
• Law of the excluded middle
• $A \rightarrow B$

 	
IF traffic light red
THEN STOP!
	• Lack of the exact knowledge that still enable us to reach a perfectly reliable conclusion
	• 3 approaches to deal with it:
	  ○ Probability theory
	  ○ Certainty factors
	  ○ Fuzzy sets
	
	
	IF pay attention during class
	THEN pass Artificial Intelligence

Probability Theory

- Probability of an event A occurring given that another event B has already occurred.
- Formulas:

Bayesian Rule / Baye's Theorem

$$p(B \cap A) = p(B|A) \times p(A)$$

$$p(A \cap B) = p(B|A) \times p(A)$$

$$p(A|B) = \frac{p(A \cap B)}{p(B)}$$

$$P(H \mid E) = \frac{P(E \mid H) * P(H)}{P(E)}$$

Certainty Factor

- An expert system can propagate CFs via rules to give CFs to conclusions.
- Rules:
  - **CF(A and B) = min(CF(A), CF(B))**
  - **CF(A or B) = max(CF(A), CF(B))**
- Different evidence / rule with the same conclusion:

$$
\begin{cases}
CF1 + CF2 - CF1 * CF2 & \text{if both are positive,} \\
CF1 + CF2 + CF1 * CF2 & \text{if both are negative,} \\
\dfrac{CF1 + CF2}{1 - \min(|CF1|, |CF2|)} & \text{otherwise}
\end{cases}
$$

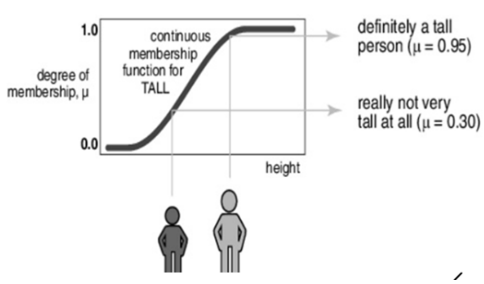
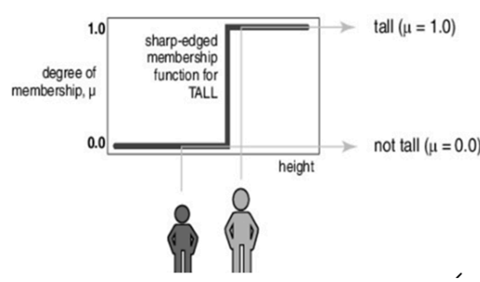
- Drawbacks:
  - Assumption of independent probabilities
    - The certainty factor of two rules in an inference chain is calculated as independent probabilities
  - CF is not being rigorously founded
    - The use of CFs has been criticized (with some justification) for not being rigorously founded.

C13: Fuzzy Logic

* Fuzzy Logic

- A **form of many-valued logic where the truth value of variables may be any real number between 0 and 1**, representing **degrees of truth** rather than the binary true or false found in classical Boolean logic.
- It is employed to **handle the concept of partial truth**, where the **truth value may range between completely true and completely false**.
- Boolean logic uses sharp distinctions. It forces us to draw lines between members of a class and non-members.

* Fuzzy Set VS Crisps Set

	Fuzzy Set	**Crisps Set**
Definition	A set where an **element can partially belong to the set**	A set where an **element either belongs or does not belong, no in-between**
Membership	Any value **between 0 and 1** (inclusive)	**Only 0 or 1** (binary)
Example	Set of people height ● Line drawn at 180 cm to differentiate between tall man and a short man ● Person A (height 181cm) → 0.82 tall ● Person B (height 179cm) → 0.78tall  	Set of people height ● Line drawn at 180 cm to differentiate between tall man and a short man ● Person A (height 181cm) → Tall ● Person B (height 179cm) → Short 

Fuzzy Rule

- Fuzzy rule can be defined as a conditional statement in the form:

IF x is A
THEN y is B

Linguistic values

Linguistic variables

Example:

IF Weight is Heavy THEN Water Level is High

A classic IF-THEN rule uses binary logic, for example,

Rule: 1		**Rule: 2**	
IF	**speed is > 100**	**IF**	**speed is < 40**
THEN	**stopping_distance is <u>long</u>**	**THEN**	**stopping_distance is <u>short</u>**

-]

We can also represent the stopping distance rules in a fuzzy form:

Rule: 1		**Rule: 2**	
IF	**speed is fast**	**IF**	**speed is slow**
THEN	**stopping_distance is <u>long</u>**	**THEN**	**stopping_distance is <u>short</u>**

-

* Applications of Fuzzy Logic

Washing Machines (Smart Appliances)	• **Adjust washing time** and **water level** based on **dirtiness, load size, and fabric type** • Why fuzzy logic? Inputs like "very dirty" or "light load" are not binary and require graded reasoning.
Air Conditioners	• Maintain a comfortable room temperature by **adjusting fan speed and cooling based on room conditions**. • Fuzzy input: "Slight warm", "very hot", etc • Smoother and smarter control compared to traditional ON/OFF systems
Automatic Transmission Systems (Cars)	• Decide **gear shifting based on driver behavior, speed and road conditions** • Why fuzzy logic? Inputs like "moderate acceleration" or "slight incline" are not clear-cut.

Camera Autofocus	• **Adjusts focus based on object sharpness, distance and lighting** • Fuzzy input: "Slightly blurry", "somewhat bright", etc • More natural and adaptive focusing