Optical Communication and Pattern Recognition

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Contents

- Introduction of Fiber optics
- Light propagation in optical fibers
- Different Optical index fibers
  - Light propagation in graded-index fiber
- Development of Intelligent Fiber Optic
- DL in Optical Communications
- Advantages of Optical fiber

- Introduction of Pattern Recognition
- Human Vs Machine Perception
- Pattern Recognition: What do you see?
- Pattern recognition and related fields
- Pattern Recognition Systems
- Pattern Classification
- Limitation of PR Systems
- The Future of Pattern Recognition.

Introduction of Fiber optics:

- The major demand placed on telecommunication systems is for more information-carrying capacity because the volume of information produced (and required) increases rapidly.
- Information-carrying capacity is proportional to channel (transmission) bandwidth the channel bandwidth needs to be increased.
- Optical fibers they are normally made of hair-thin high purity silica glass, covered with plastic.

Cu wire → ~ 100 kHz
Coax cable → ~ 100 MHz
Radio → ~ 100 MHz
Radio → ~ 100 GHz
Optical → ~ 1000 THz

- **The ranges of Information transmission:**
  - A copper wire can carry a signal up to several hundred kHz over several tens of kms of distance.
  - A coaxial cable can propagate a signal up to several hundreds of MHz.
  - Radio transmission is in the range of 500 kHz to 100 MHz. Microwaves, including satellite channels, operate up to 100 GHz.
  - Optical communications uses light as the carrier, light frequency is between 100 and 1000 THz (T = 10^12).
  - Therefore, optical systems have the largest capacity for information transmission.

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Light propagation in optical fibers:

- The simplest way to view light in fiber optics is by ray theory. In this theory, the light is treated as a simple ray, shown by a line. An arrow on the line shows the direction of propagation.
  - The speed of light in vacuum is: c = 300,000 km/s
  - However, the speed of light in medium is more slowly, v = c / n.
  - The ratio of the velocity of light, c, in vacuum, to the velocity of light in the medium, v, is the refractive index, n.

$$n = c / v$$

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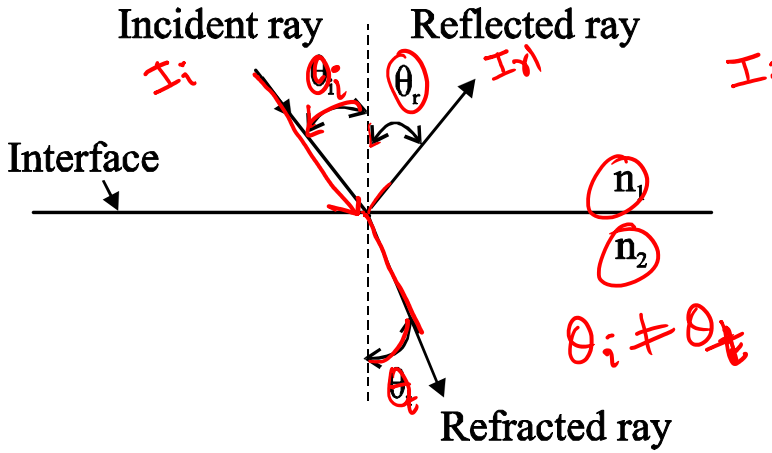
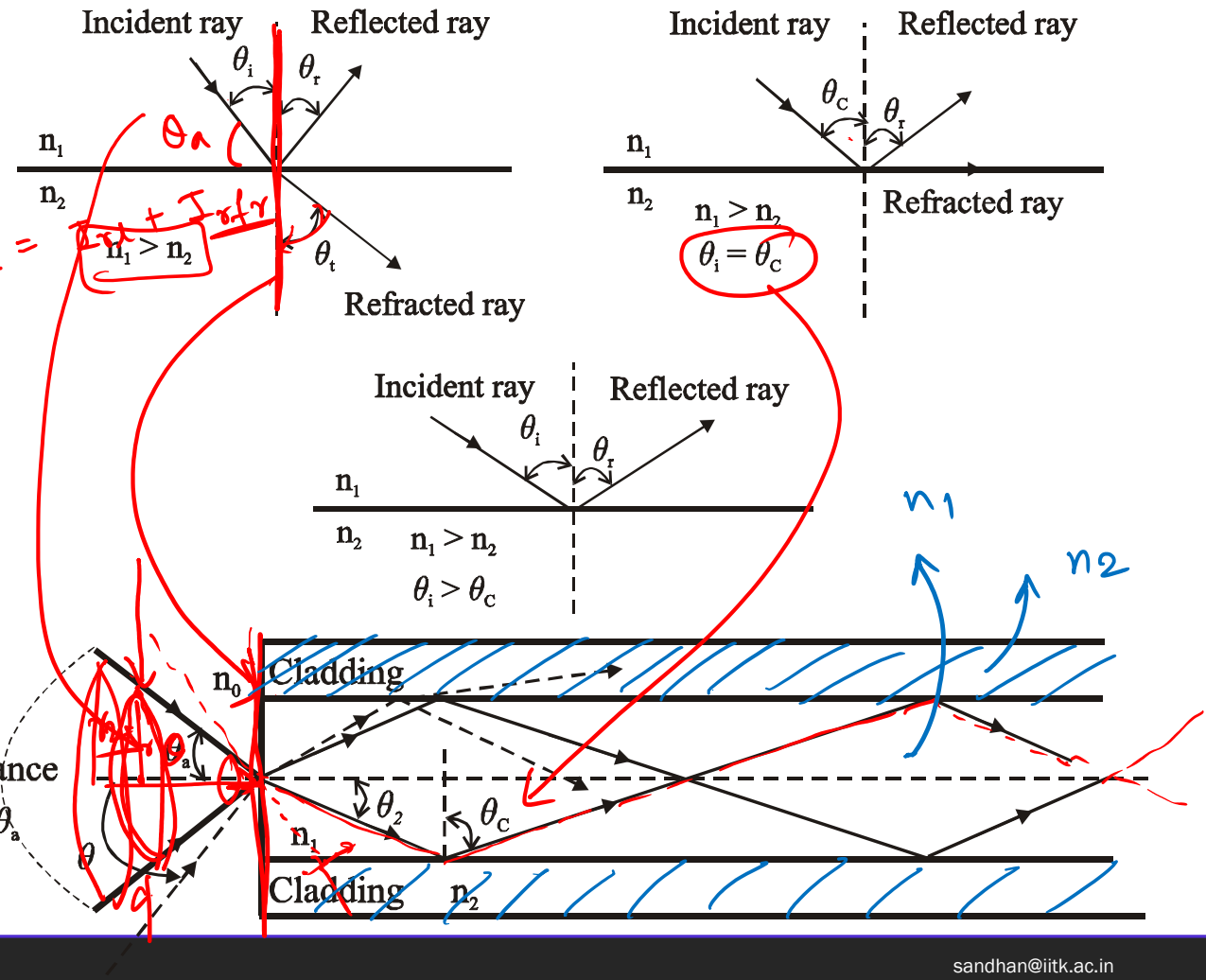
Light propagation in optical fibers:

- Light traveling from one material to another causes the change of speed, which results in the change of light traveling direction.
- This deflection of light is called refraction.





- **Acceptance angle**: Acceptance angle, Θa, is the maximum angle over which light rays entering the fiber will be guided along its core.

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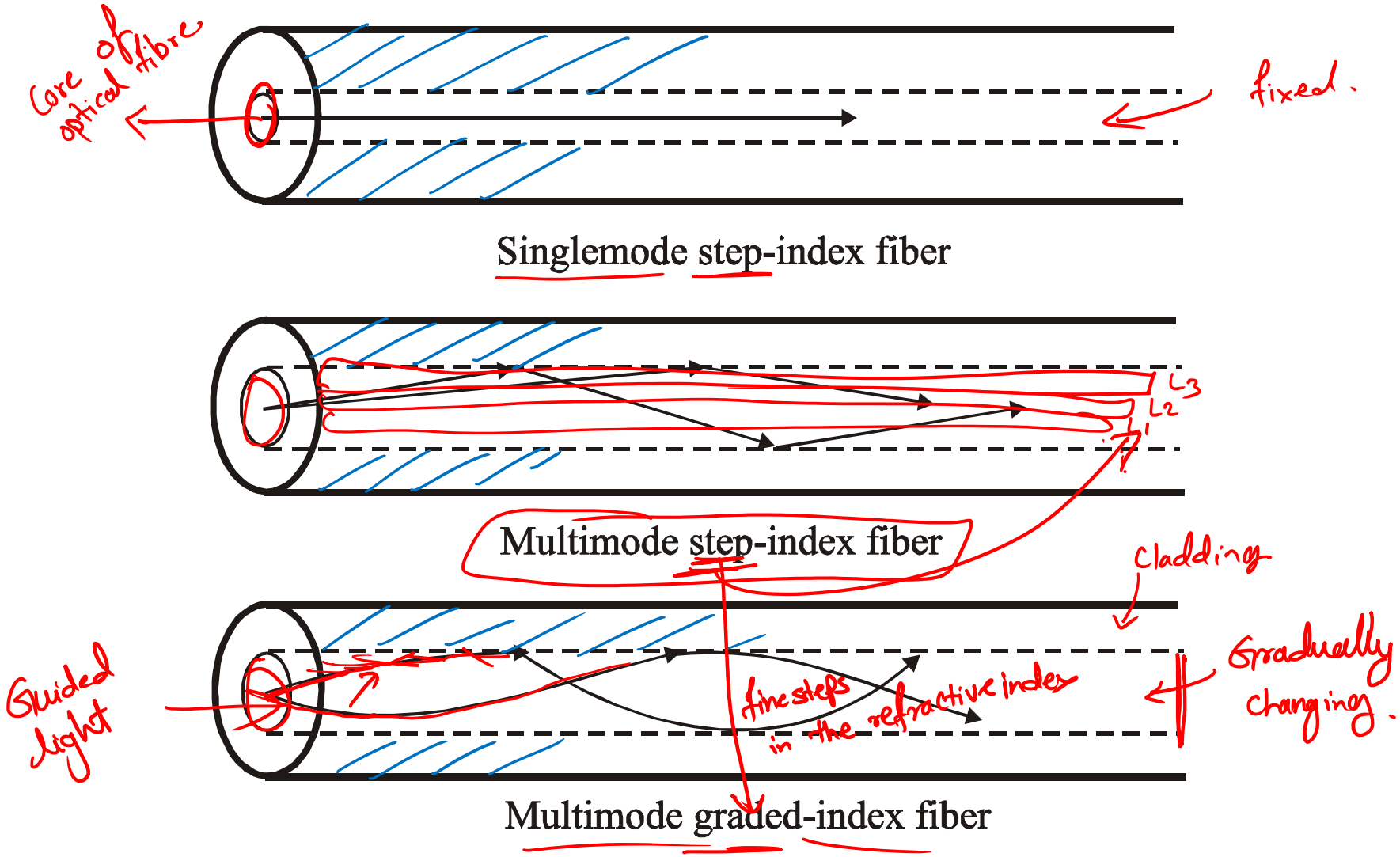
Different Optical index fibers:



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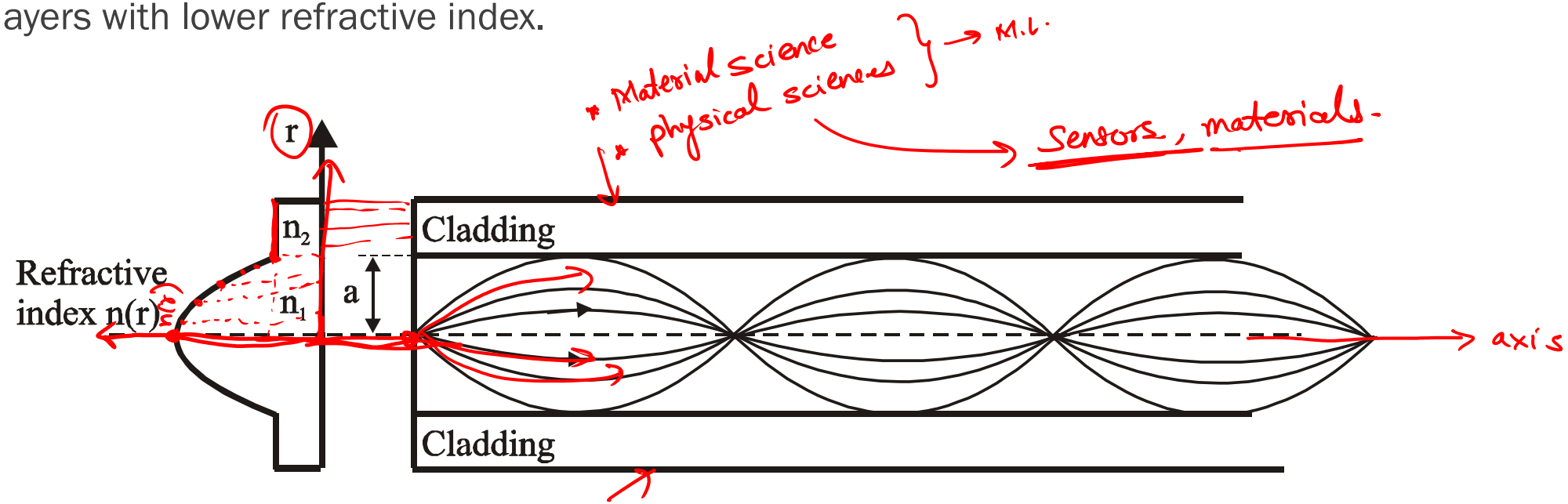
Light propagation in graded-index fiber

- It guides light by refraction.
- Its refractive index decreases gradually away from its center, dropping to the same as the cladding at the edge of the core.
- The change in refractive index causes refraction, bending light rays back toward the axis as they pass through layers with lower refractive index.



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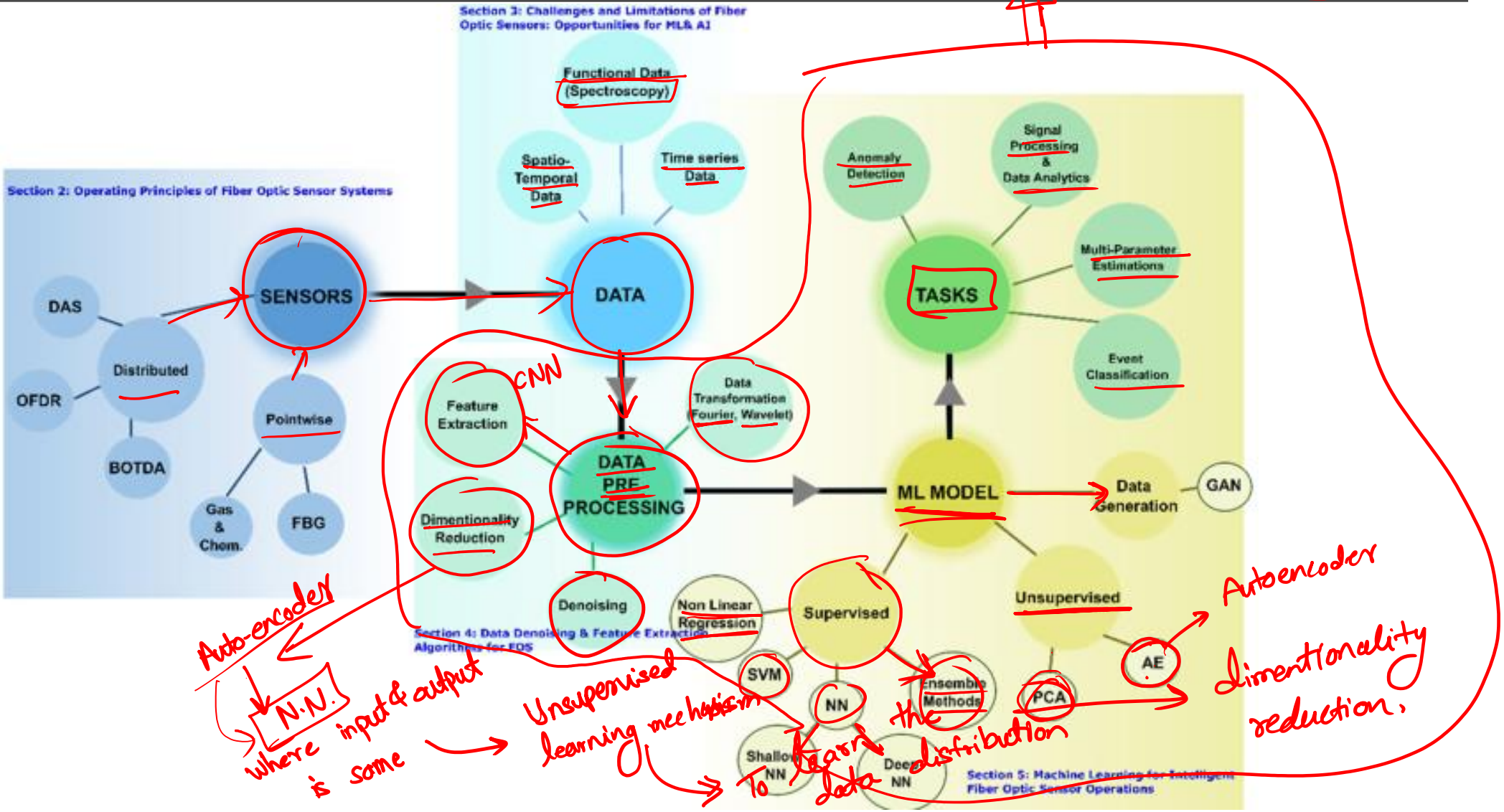
Development of Intelligent Fiber Optic:



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DL in Optical Communications:

- Techniques from artificial intelligence (AI) have been widely applied in optical communication and networks, evolving from early machine learning (ML) to the recent deep learning (DL).

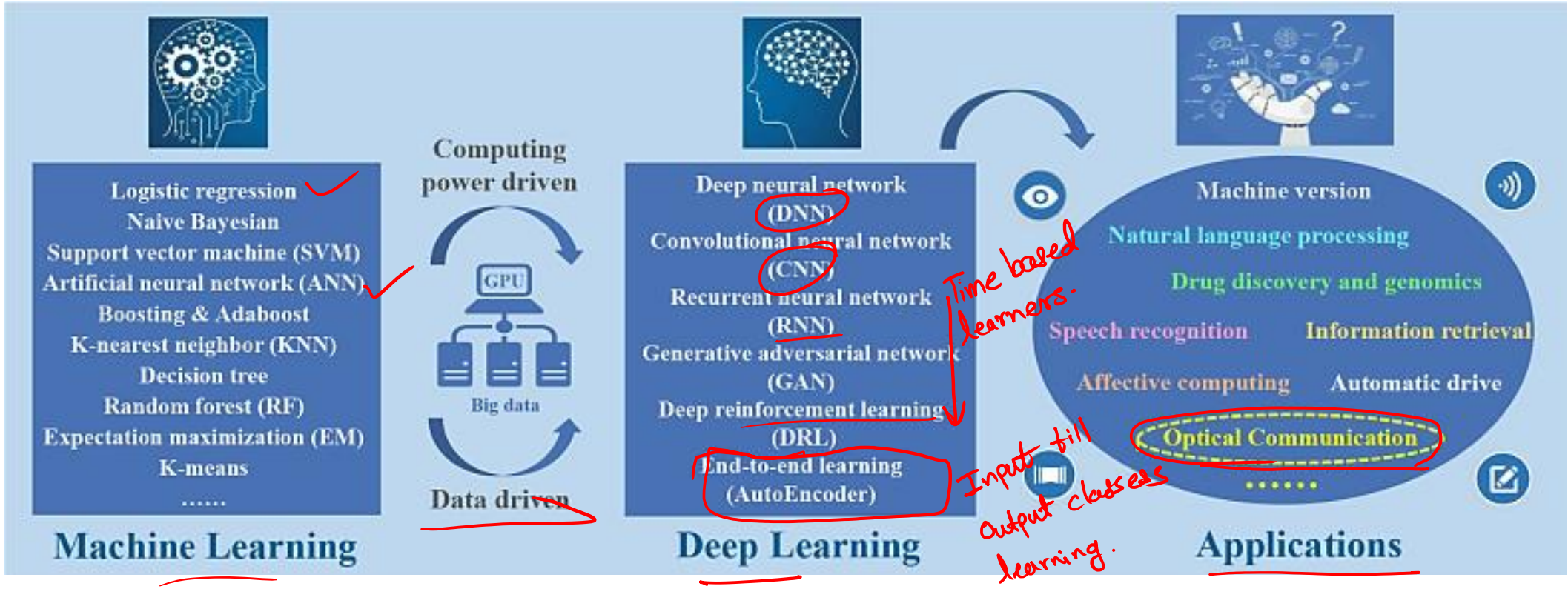
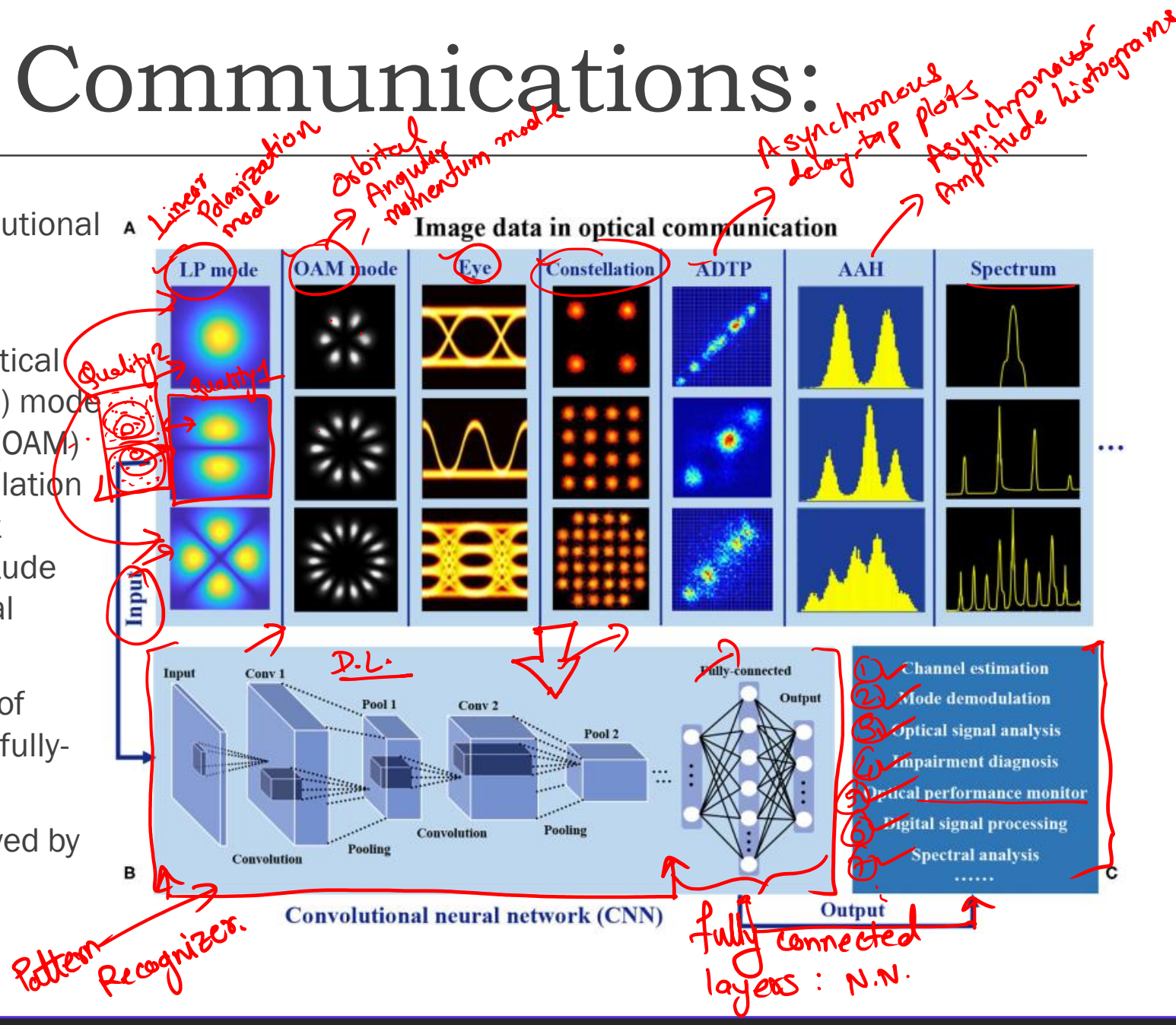


FIGURE: Advances in artificial intelligence in optical communications. Driven by powerful parallel computing capacity and big data, traditional machine learning algorithms are progressing to deep learning techniques with a variety of applications, promoting the evolution of optical communications toward intelligence.

DL in Optical Communications:

- From given figure application of convolutional neural network (CNN) in optical communication for image processing.
- (A) Summarization of image data in optical communication: linear polarization (LP) mode diagrams, orbital angular momentum (OAM) mode diagrams, eye diagrams, constellation diagrams, asynchronous delay-tap plot (ADTP) diagrams, asynchronous amplitude histograms (AAH) diagrams, and optical spectrum diagrams.
- (B) The structure of CNN is composed of convolution layers, pooling layers, and fully-connected layers.
- (C) A variety of functions can be achieved by CNN for optical communication



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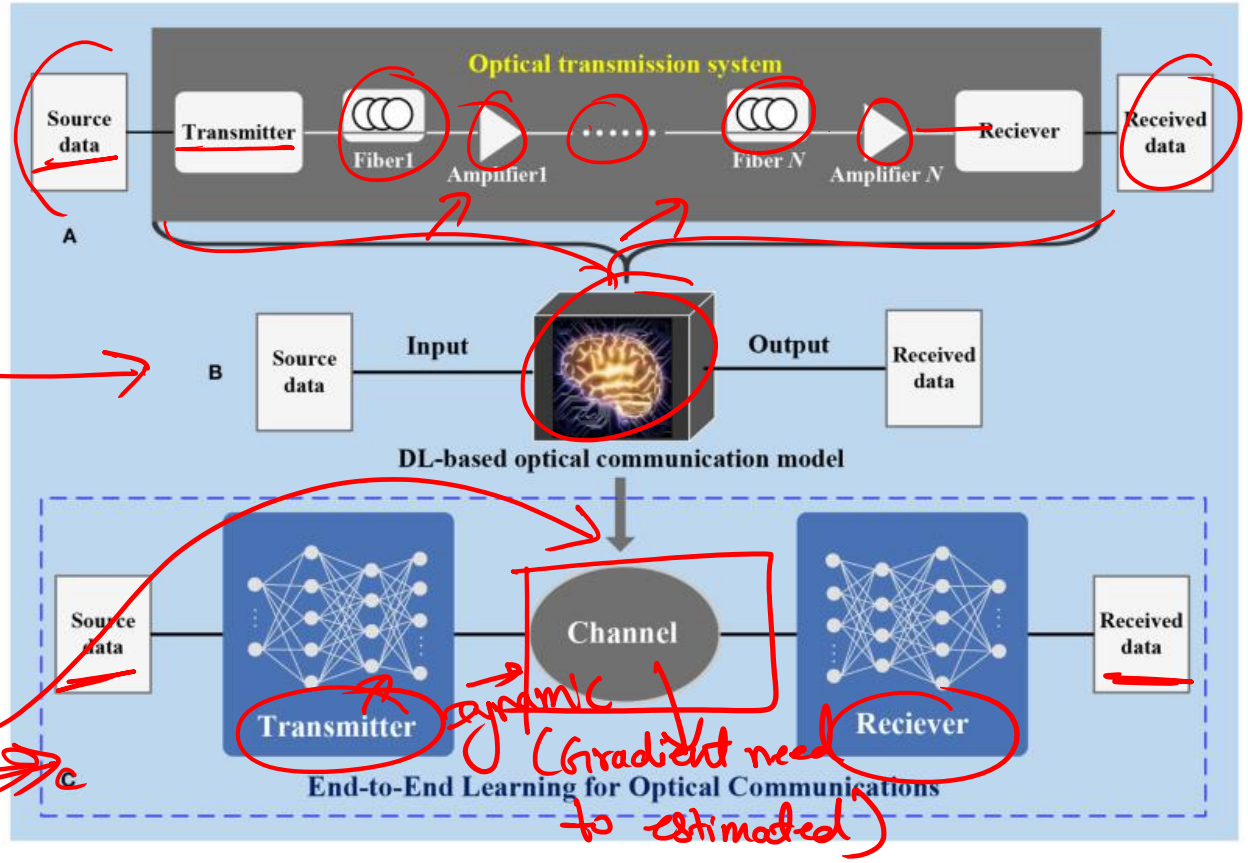
DL in Optical Communications:

- From given fig the deep learning for optical communication modeling.
- (A) The conventional block-based optical communication system, constructed in a divide-and-conquer manner using a series of model blocks.
- (B) Deep learning-based optical communication model, built by the data-driven multi-layer neural network.
- (C) Schematic of end-to-end learning for optical communication, based on the DL-based channel model



Advantages

- **Advantages:**
  - Fiber optics are not susceptible to electromagnetic interference (because they are insulators) and therefore have small crosstalk.
  - It gives high security (cannot be tapped, no sparks)
  - These are cheaper (abundant raw material)
  - Have lower weight, smaller size and are more flexible (thus are easier to install);
  - These are corrosion resistant (thus have longer operating lifetimes)

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Introduction of Pattern Recognition:

- **What is a Pattern?**
  - A set of instances that share some regularities and similarities is repeatable

- **What is Pattern Recognition?**
  - Pattern recognition (PR) is the scientific discipline that concerns the description and classification (recognition) of patterns (objects)
  - PR techniques are an important component of intelligent systems and are used for many application domains
    - Decision making
    - Object and pattern classification

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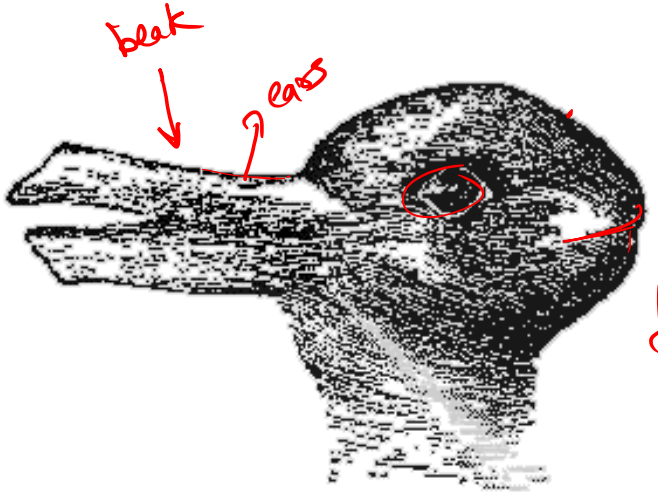
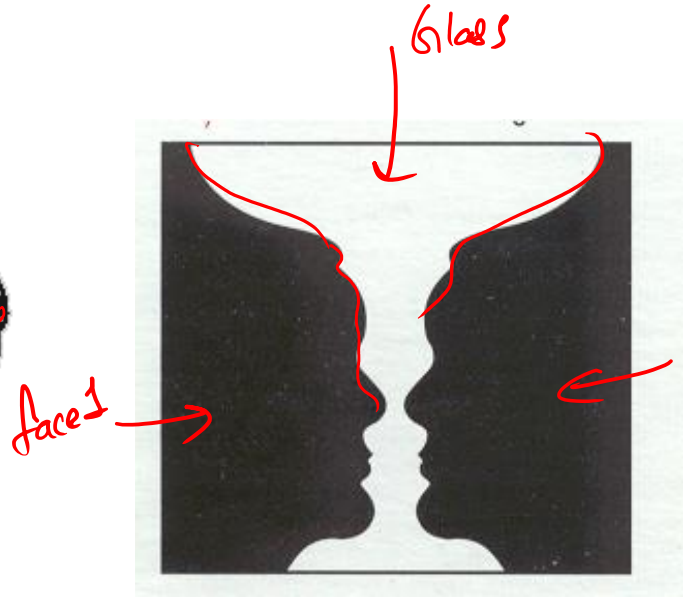
Human Vs Machine Perception

- Humans have developed highly sophisticated skills for sensing their environment and taking actions according to what they observe, e.g., I recognizing a face, I understanding spoken words, I reading handwriting, I distinguishing fresh food from its smell.
- Each person's face is a pattern composed of a particular combination of structures (eyes, nose, mouth, …) located in certain positions on the face.
- By analyzing sample images of faces, a program should be able to capture the pattern specific to a face and identify (or recognize) it as a face (as a member of a category or class we already know); this would be **pattern recognition.**
- **Machine Perception:**
- Through programming machines can recognize, Speech recognition Fingerprint identification, OCR (Optical Character Recognition), DNA sequence identification.

Pattern Recognition: What do you see?

- Two or more patterns can exist within on image or thing
- Humans can only actively see one pattern at a time.
  - Examples of this are visual illusions





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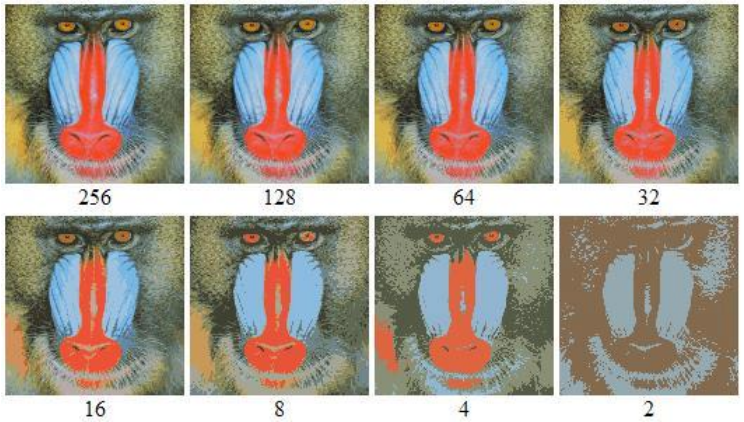
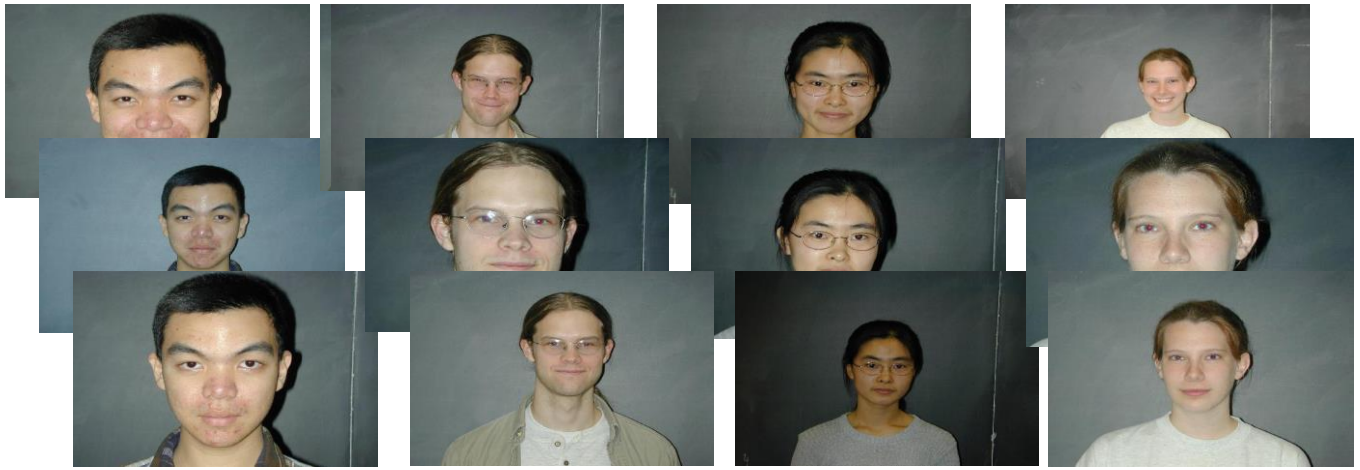
Pattern Recognition: What do you see?

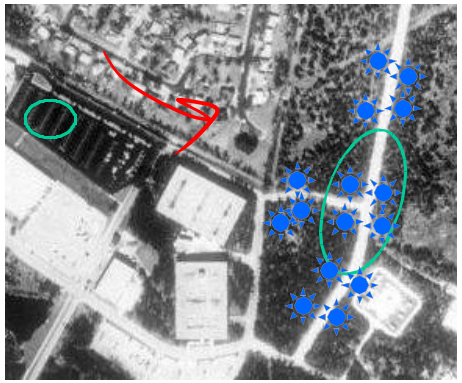
- Example - Color Image Compression:



- Example – Face Recognition



- Automatic Target Recognition

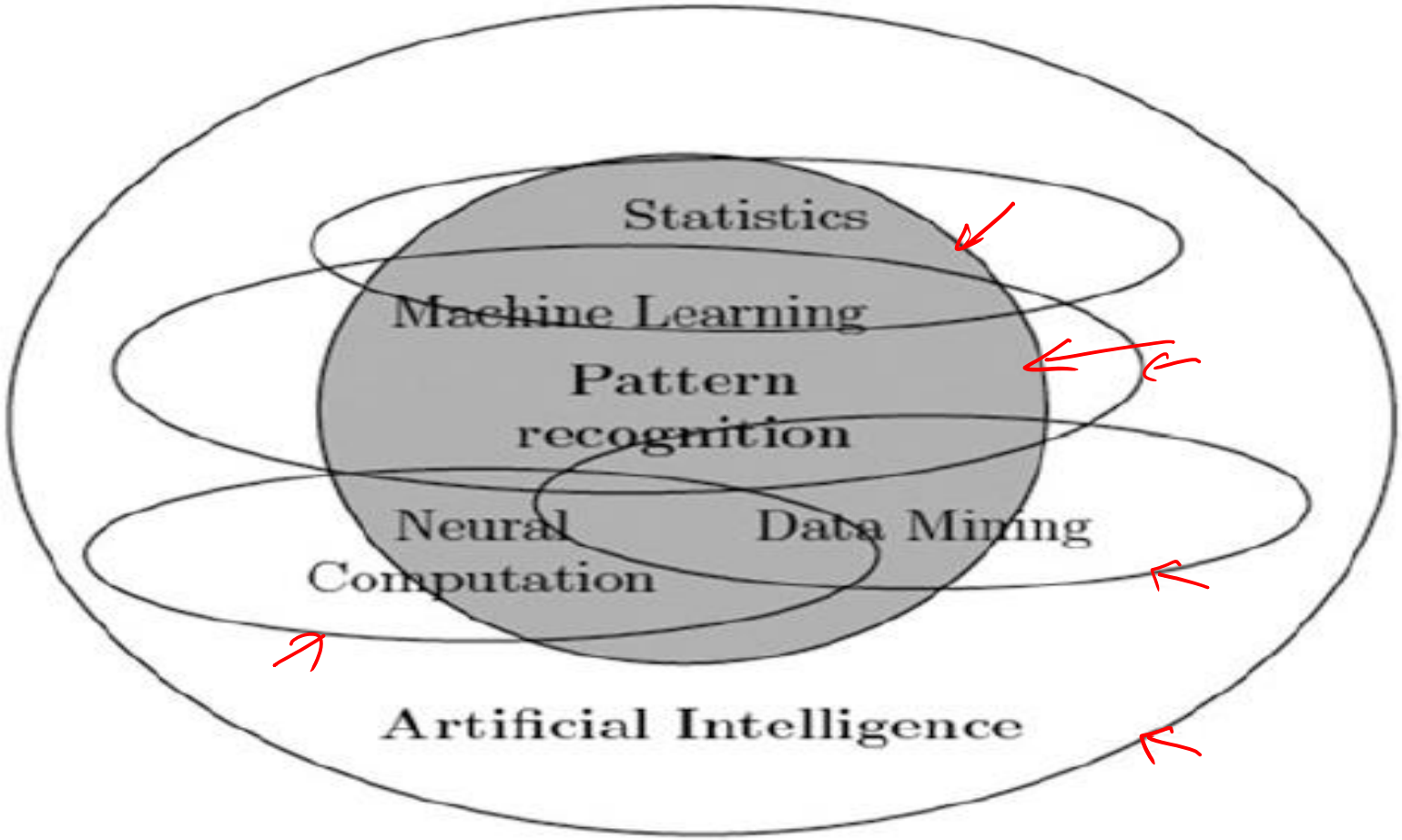


Harley Motocycle

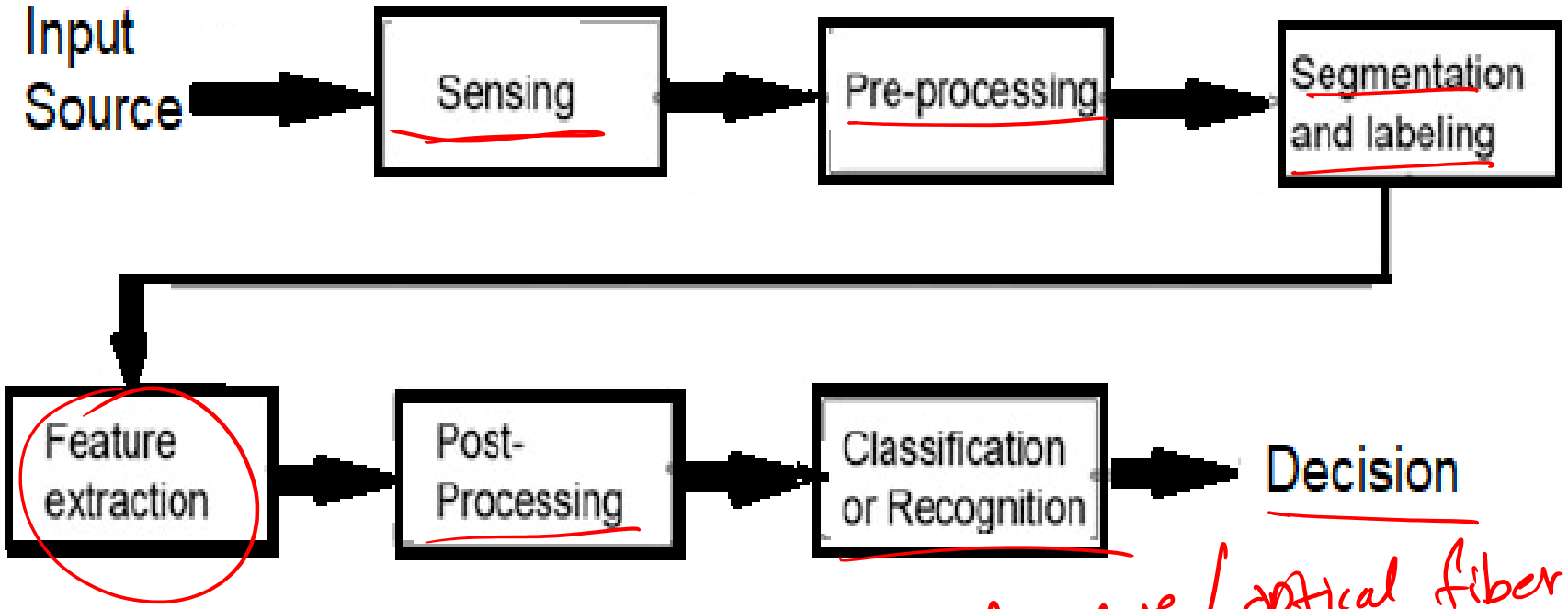
Ford 350

Ford 250

Pattern recognition and related fields



Pattern Recognition Systems



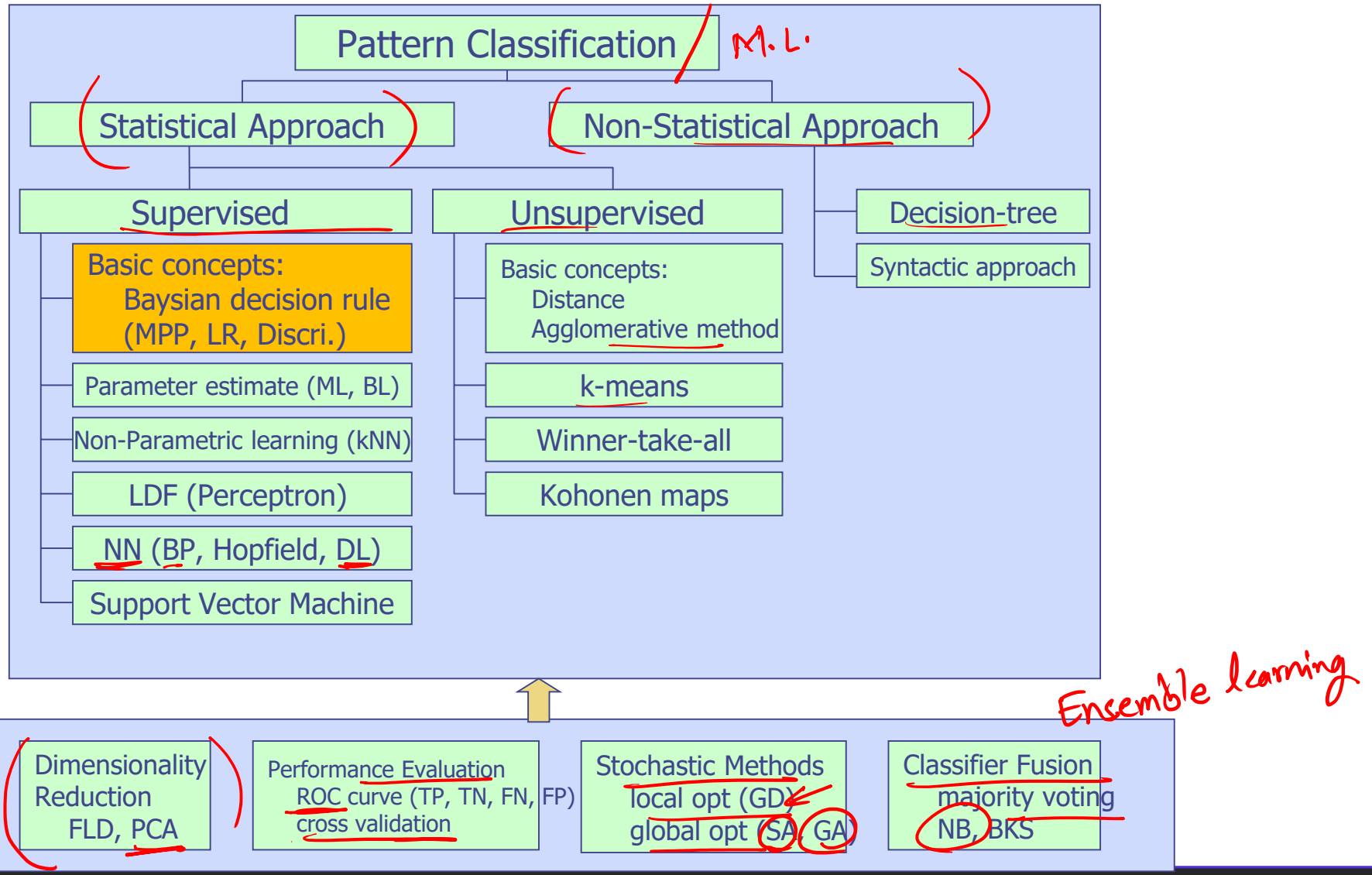
- Data acquisition and sensing
  - Use of a transducer (camera or microphone)
  - Important issues: bandwidth, resolution, sensitivity, distortion, SNR, latency, etc.

optical sensors / optical fiber system

Pattern Recognition Systems

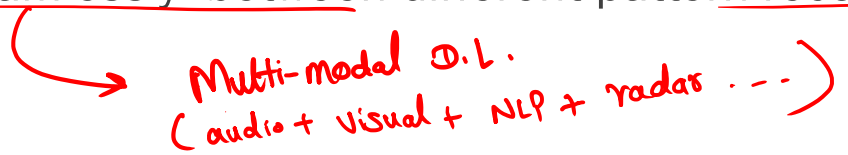
- Pre-processing:
  - Removal of noise in data.
  - Isolation of patterns of interest from the background
- Segmentation and grouping
  - Patterns should be well separated and should not overlap
- Feature extraction
  - Finding a new representation in terms of features
    - Discriminative features
    - Invariant features with respect to translation, rotation and scale.
- Post Processing
  - Exploit context input dependent information other than from the target pattern itself to improve performance
- Classification
  - Use a feature vector provided by a feature extractor to assign the object to a category

Pattern Classification

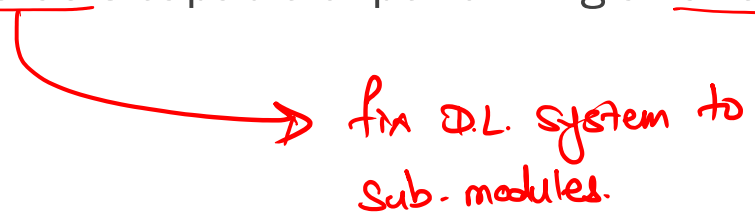


Limitation of PR Systems

- Human have the ability to switch rapidly and seamlessly between different pattern recognition tasks.



- It is very difficult to design a device that is capable of performing a variety of different classification tasks as human.



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The Future of Pattern Recognition…

- Computer's have efficiently mastered some forms of pattern recognition.

- If all intellectual activity is made up of pattern recognition, might further development of pattern recognition be another route to artificial intelligence?

- Deep learning: efficient visual pattern recognizer : D.L. CNN

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Thank you

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