Please provide the introduction / overview on this lesson

☒ A : Text-based + Audio
☐ B : Text-based + Video
☐ C : Only Video

Overview

In this chapter, you are going to learn about:

- Definition of video
- How to calculate total size of a video per second
- General knowledge of lossless compression
- How to calculate entropy of an input string

1. Introduction > 1.2 Learning Content

Please make sure the hierarch of the content is well formed.
Please organize the lesson in 3-5 main topics and use 3-level headings.

Level 1	Level 2	Level 3
1. Introduction to Video	1.1 Properties of Videos	
	1.2 Video Calculation	
2. Introduction to Lossless Compression	2.1 Concept of Lossless Compression	
	2.2 Entropy	

ID Will do it by looking at 1.1 Lesson overview

Image Processing	
I. General knowledge in image p rocessing and multimedia	1. Introduction to Image Processing 2. Data Structure and Color of Images 3. Ms. Visual Studio 2008 and OpenCV 4. Introduction to Multimedia Systems 5. Introduction to Video and Lossless Compression 6. Huffman Coding 7. LZ77 8. LZ78 9. LZW
II. Advance knowledge in image segmentation and luminance	10. Sampling 11. Image Segmentation-I 12. Image Segmentation-II 13. Luminance and Histogram Equalization

1. Introduction > 1.4 Learning Objectives

Please provide objective of the lesson by high light keyword and follow (Audience, Behavior, Condition, Degree) to write the objective

☒ A : Text-based + Audio
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☐ C : Only Video

Objective
Upon completion of this chapter, you will be able to: • Use a formula to calculate total size of a **video** per second • Use a formula to calculate **entropy** of an input string

Please provide keywords of the lesson with explanation

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Keywords	Description
Data compression ratio	also known as **compression power** is a computer science term used to quantify the reduction in da ta-representation size produced by a data compression algorithm.
Self information	or **surprisal** is a measure of the information content associated with an event in a probability space or with the value of a discrete random variable. It is expressed in a unit of information, for example b its, nats, or hartleys, depending on the base of the logarithm used in its calculation.
Lower bound	is defined dually as an element of **partially ordered set** which is less than or equal to every element of **subset**.

2. Learn> Topic: 1. Introduction to Video

(1) Learning Contents	☐ A : Text-based + Audio ☒ B : Text-based + Video ☐ C : Only Video
	▪ Q: What is a **video**? ▪ A: A **video** is a set of image which displays per second. ➢ Each image is called **frame**. ➢ We denote as “f/s” (frame per second). ➢ We can choose number of images, e.g., 15f/s, 30f/s, 45f/s, or so on.

2. Learn> Topic: 1.1 Properties of Videos

(1) Learning Contents

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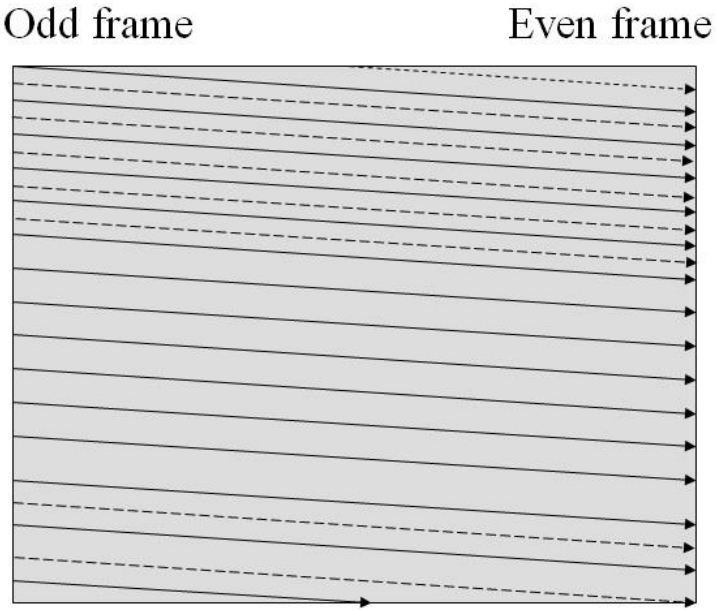
- For analog video, frames are divided into 2 types.
  1) **Even frame:** detect only even number, e.g., 2, 4, 6, and so on.
  2) **Odd frame:** detect only odd number, e.g., 1, 3, 5, and so on.

- Q: Why do we need to know even and odd frame?
- A: We need know about which frame is even and which frame is odd because:
  - ➢ We want to do operations only on even or odd frames
  - ➢ We want to keep information of even or odd frames

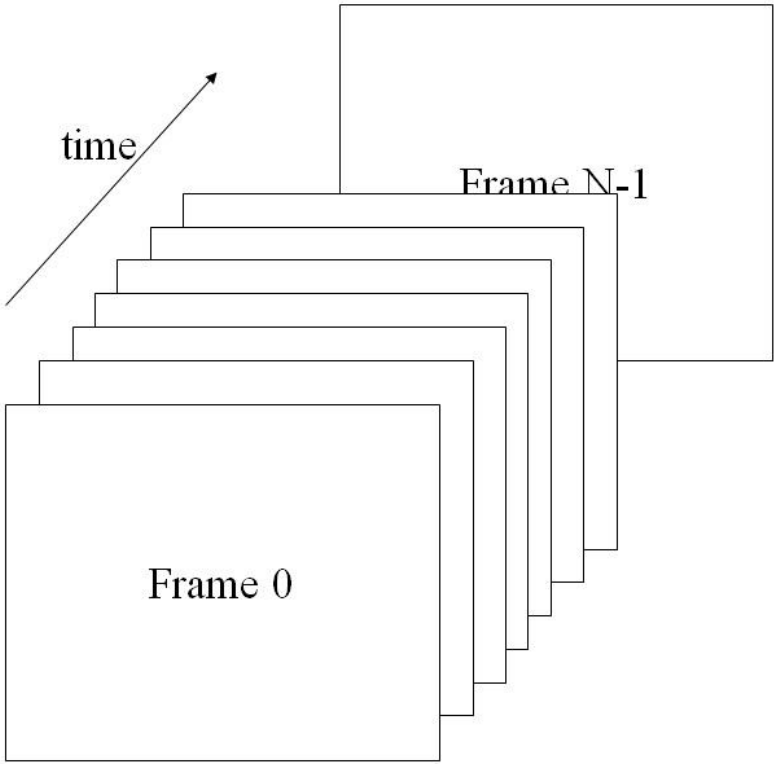


2. Learn> Topic: 1.1 Properties of Videos

(1) Learning Contents

☒ A : Text-based + Audio
☐ B : Text-based + Video
☐ C : Only Video

- Digital video is digitized version of a 3D function: f(x,y,t).
  - **x:** is x axis.
  - **y:** is y axis.
  - **t:** is time.



(1) Learning Contents

☒ A : Text-based + Audio
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- The videos files usually have extensions:
  - **AVI: A**udio **V**ideo **I**nterleave is a multimedia container format introduced by **Microsoft** in November **1992**.
  - **MOV and QT:** Quick Time is a multimedia framework developed by **Apple Computer Inc**.
  - **MPEG-4 Part 14 (MP4):** (**M**oving **P**icture **E**xperts **G**roup) is a format for wo rking with video files and was first introduced in **1998**. It allows streaming o ver the Internet.
  - **FLV: F**lash **V**ideois is a container file format used to deliver video over the I nternet using **Adobe Flash Player** version 6 and newer.

AVI

2. Learn> Topic: 1.2 Video Calculation

(1) Learning Contents

☒ A : Text-based + Audio
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- Q: How to calculate total size of a video per second?
- A: In order to calculate total size of a video per second, we have to know:
  - **Resolution of an image (R):** Width x Height
  - **Number of frame per second (Nf):** How many frames we need per second
  - **Number of bits (Nb):** How many bits we need to use, e.g., 8 bits = 1 byte, 24 bits = 3 bytes.
- We can get a formula of total size of a video per second (**Vs**) by:
  - **Vs = R . Nf . Nb** (bytes)

- If we want to calculate total size of a video per ***n*** second (**Vns**) by:
  - **Vns = R . Nf . Nb . n = Vs . n** (bytes)

(1) Learning Contents

☒ A : Text-based + Audio
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▪ Example1: Calculate total size of a video in 1h30mn? If we know a raw video wit h:

- Resolution of an image (R) is 640x480.
- Number of frame per second (Nf) is 30f/s.
- Number of bits (Nb) is 24 bits color.

▪ First, we calculate total size of a video per second (**Vs**):

- **Vs = R . Nf . Nb** = 640x480x30x3 = 27648000 bytes

▪ Then we calculate total size of a video in 1h30mn (**Vns**) by:

- n = 1h30mn = 3600 + (30x60) = 3600 + 1800 = 5400 seconds
- **Vns = R . Nf . Nb . n = Vs . n** = 27648000x5400 = 1492992.10^5 bytes

(1) Learning Contents

☒ A : Text-based + Audio
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- Example2: Calculate total size of a video in 70mn? If we know a raw video with:
  - Resolution of an image (R) is 1024x1024.
  - Number of frame per second (Nf) is 60f/s.
  - Number of bits (Nb) is 8 bits.

- First, we calculate total size of a video per second (**Vs**):
  - **Vs = R . Nf . Nb** = 1024x1024x60x1 = 62914560 bytes

- Then we calculate total size of a video in 1h30mn (**Vns**) by:
  - n = 70mn = 70x60 = 4200 seconds
  - **Vns = R . Nf . Nb . n = Vs . n** = 62914560x4200 = 264241152.10^3 bytes

2. Learn> Topic: 2. Introduction to Lossless Compression

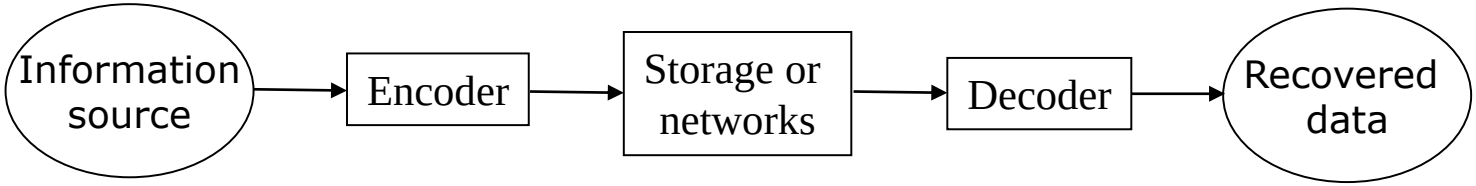
(1) Learning Contents	☐ A : Text-based + Audio ☒ B : Text-based + Video ☐ C : Only Video
	▪ There are two types of compression: ➢ Lossless compression: The recovered data is exactly the same as the input data. ➢ Lossy compression: The recovered data approximates the input data. ▪ Compress methods are key enabling techniques for multimedia applications. ▪ Raw media takes much storage and bandwidth, for example, videos. ▪ So, we have to compress it before transmitting through network.

2. Learn> Topic: 2.1 Concept of Lossless Compression

(1) Learning Contents

☒ A : Text-based + Audio
☐ B : Text-based + Video
☐ C : Only Video

▪ Concept of lossless compression is:



- Information source or input data: is a sequence of symbols from an alphabet.
- Encoder or compression: is a sequence of code words.
- Storage or network: is place to store encode data in local or network.
- Decoder or decompression: is a sequence of alphabet.
- Recovered data: is a sequence of symbols from an alphabet which is exactly the same as input data.

▪ Compression ratio = bits used to represent the input data (uncompressed size) / bits of the code (compressed size)
▪ Example: A representation that compresses a **10MB** file to **2MB** has a compression ratio of 10/2 = 5.

(1) Learning Contents

☒ A : Text-based + Audio
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- Q: What is **entropy**?
- A: **Entropy** is the number of bits needed to encode a media source which is lowe r bounded.

- If we want to calculate the entropy, we have to know about **self information**.
- **Self information** of an event **A** is defined as: $\mathbf{-\log_b P(A)}$ or $\mathbf{\log_b [1/P(A)]}$
  - where **P(A)** is the probability of even **A**.
  - if **b** equals **2**, the unit is "**bits**".
  - if **b** equals **e**, the unit is "**nats**".
  - if **b** is **10**, the unit is "**hartleys**".

(1) Learning Contents

☐ A : Text-based + Audio
☒ B : Text-based + Video
☐ C : Only Video

- Example: A source outputs two symbols (the alphabet has 2 symbols) 0 or 1. P(0) = 0.25 and P(1) = 0.75.

- Information that we get when receiving a 0 is:
  - $\log_2(1/0.25) = \log_2 4 = 2$ bit

- Information that we get when receiving a 0 is:
  - $\log_2(1/0.75) = \log_2 1.3333 = 0.415$ bit

(1) Learning Contents

☒ A : Text-based + Audio
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- It has some properties of self information:
  - The letter with smaller probability has high self information.
  - The letter with bigger probability has low self information.
  - The measure of self information is positive and additive.
  - The information we get when receiving two independent letters are summat ion of each of the self information.
    - $-\log_2 P(s_a, s_b)$
    - $= -\log_2 P(s_a)P(s_b)$
    - $= [-\log_2 P(s_a)] + [-\log_2 P(s_b)]$
    - $= \log_2[1/P(s_a)] + \log_2[1/P(s_b)]$

(1) Learning Contents

☐ A : Text-based + Audio
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▪ An source has symbols {s_1, s_2, …, s_n}, and the symbols are independent, the ave rage self-information is defined as following formula:

- $\boldsymbol{H} = \sum_{i=1}^{n} P(s_i) log_2(1/P(si))$ (bits)

▪ ***H*** is called the **entropy** of the source.

(1) Learning Contents

☐ A : Text-based + Audio
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- Example: A source outputs two symbols (the alphabet has 2 letters) 0 or 1. P(0) = 0.25, P(1) = 0.75.
  - $\boldsymbol{H} = P(0)\log_2[1/P(0)] + P(1)\log_2[1/P(1)]$
  - $\boldsymbol{H} = 0.25 \times \log_2(1/0.25) + 0.75 \times \log_2(1/0.75)$
  - $\boldsymbol{H} = 0.8113$ bit

- Thus, we need at least 0.8113 bit per symbol in encoding.

(1) Learning Contents

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▪ A grey scale image with 256 possible levels. A={0, 1, 2, …, 255}. Assuming the pixels are independent and the grey scales are have equal probabilities:

- Total symbols = 256
- P(0) = 1/256, P(1)= 1/256, …, P(255) = 1/256
- ***H*** = $[-P(0)\log_2(P(0))] + [-P(1)\log_2(P(1))] + \ldots + [-P(255)\log_2(P(255))]$
- ***H*** = $256 \times 1/256 \times \log_2(256)$
- ***H*** = 8 bits

▪ What about an image with only 2 levels 0 and 255?

- Assuming, P(0) = 0.5 and P(255) = 0.5
- ***H*** = $[-P(0)\log_2(P(0))] + [-P(255)\log_2(P(255))]$
- ***H*** = $0.5 \times \log_2(1/0.5) + 0.5 \times \log_2(1/0.5)$
- ***H*** = 1 bit

(1) Learning Contents

☒ A : Text-based + Audio
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- In order to estimate the entropy, we assume that the symbols are independent.

- Example1: Find the entropy of following string?
  - Input string: aaabbbbccccdd
- A: We can use formula of the entropy (***H***), but:
  - First, we have to find total number of symbols or letters: $n = 13$
  - Then we find probability of each symbol:
    - P(a) = 3/13 = 0.2307
    - P(b) = 4/13 = 0.3076
    - P(c) = 4/13 = 0.3076
    - P(d) = 2/13 = 0.1538
  - $H = P(a)\log_2(1/P(a)) + P(b)\log_2(1/P(b)) + P(c)\log_2(1/P(c)) + P(d)\log_2(1/P(d))$
  - $H = 0.2307\log_2(1/0.2307) + 0.3076\log_2(1/0.3076) + 0.3076\log_2(1/0.3076) + 0.1538\log_2(1/0.1538)$
  - $H = 1.95$ bit

(1) Learning Contents

☒ A : Text-based + Audio
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- Example2: Find the entropy of following string?
  - Input string: abacdabedcddeabedbbd
- A: We know that:
  - Total number of symbols: $n = 20$
  - Probability of each symbol:
    - P(a) = 4/20 = 0.2
    - P(b) = 5/20 = 0.25
    - P(c) = 2/20 = 0.1
    - P(d) = 6/20 = 0.3
    - P(e) = 3/20 = 0.15
  - $\boldsymbol{H} = P(a)\log_2(1/P(a)) + P(b)\log_2(1/P(b)) + P(c)\log_2(1/P(c)) + P(d)\log_2(1/P(d)) + P(e)\log_2(1/P(e))$
  - $\boldsymbol{H} = 0.2\log_2(1/0.2) + 0.25\log_2(1/0.25) + 0.1\log_2(1/0.1) + 0.3\log_2(1/0.3) + 0.15\log_2(1/0.15)$
  - $\boldsymbol{H} = 0.2(2.32) + 0.25(2) + 0.1(3.32) + 0.3(1.73) + 0.15(2.73)$
  - $\boldsymbol{H} = 0.464 + 0.5 + 0.332 + 0.519 + 0.4095$
  - $\boldsymbol{H} = 2.2245$ bits

Please give a lesson summary.
Each topic can be summarized into a sentence, diagram, or even a word.

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Summarize

- **A video** is a set of image which displays per second. Each image is called **frame**.
- Formula of total size of a video per second (**Vs**) is:
  - **Vs = R . Nf . Nb** (bytes)
- Formula of total size of a video per ***n*** second (**Vns**) is:
  - **Vns = R . Nf . Nb . n = Vs . n** (bytes)
- In order to make lossless compression, we need to know about:
  - Information source or input data
  - Encoder or compression
  - Storage or network
  - Decoder or decompression
  - Recovered data
- Formula of Entropy (**H**) in ***n*** symbols is:
  - **H =** $\sum_{i=1}^{n} P(s_i) log_2(1/P(si))$ (bits)

Provide references if you think the students need.

Reference

- http://www.winxdvd.com/resource/mov.htm
- https://en.wikipedia.org/wiki/QuickTime_File_Format
- https://en.wikipedia.org/wiki/Data_compression_ratio
- https://en.wikipedia.org/wiki/Self-information
- https://en.wikipedia.org/wiki/Entropy

4. Outro > 4.3 Assignment

Please provide the assignment such as exercise , discussion, research topic, Short essay, case studies, ...

☒ A : Text-based + Audio
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Assignment
1) Calculate total size of an video in 1h15mn? If we know: ➢ Resolution of an image: 780x640 ➢ Number of frames per second: 45f/s ➢ Number of bits: 24 bits color 2) Calculate entropy of following string: ➢ Input string: adcabcdebaabeddccead

4. Outro > 4.4 Next Lesson

This is the end of the lesson.
Ending message and introduction to next lesson including lesson title and topics should be given.

☒ A : Text-based + Audio
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Overview

- Introduce to Huffman coding tree
- Properties of Huffman coding

Next Lesson Title	**Huffman Coding** 1. Huffman Coding Tree 2. Properties of Huffman Coding