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SCHOOL OF COMPUTER SCIENCE AND ENGINEERING
CONTINUOUS ASSESSMENT TEST - I
FALL SEMESTER 2025-2026

BCSE323L- Digital Watermarking and Steganography
Answer Key

1. A music streaming service named as SoundSecure allows users to download encrypted audio tracks for offline listening. These tracks can only be played on authorized apps that can decrypt the file and detect the embedded watermarks. A user uses the SoundSecure app (authorized) to play a legal song on his smartphone. But he routed the audio output to an unauthorized recording device which saved the song as an unencrypted file. This illegally recorded version can only be played on an unauthorized app.

A) Explain how encryption and watermarking work together to prevent unauthorized distribution of digital audio content. (4 marks)

B) Describe the differences in behaviour between authorized and unauthorized apps/devices in this scenario. (3 marks)

C) What weaknesses does this system still have, and how could pirates exploit them? Suggest one way to strengthen it. (3 marks)

Answer:

A) Encryption ensures that only authorized apps can access and play the downloaded audio files. Unauthorized apps cannot directly open or use the file. Watermarking embeds invisible, user-specific information (like user ID or timestamp) directly into the audio content. This watermark remains even if the file is re-recorded and played. Together, they prevent unauthorized use (encryption) and allow tracing of leaked copies (watermarking), making it harder to pirate the content.

B) Authorized apps can decrypt and play legal audio files. They also detect watermarks and block playback if the file is illegal or tampered (e.g., re-recorded). Unauthorized apps cannot decrypt original encrypted files, but can play re-recorded, unencrypted versions because they don't detect or act on watermarks.

c) Limitation is that a user can bypass encryption by simply recording the audio output using unauthorized hardware or software, resulting in an unencrypted copy. Pirates can distribute these re-recorded files widely since unauthorized apps can play them. We can strengthen the system by using robust watermarking and monitor online platforms for pirated content. Implement traceable watermarks so that even leaked copies can lead to the source (user) and discourage misuse.

2. A watermarking system is designed to protect medical images of size 512×512 by embedding patient ID and hospital code using multibit-message watermarking with multi-symbol encoding. The watermark is successfully detected if the linear correlation exceeds 90%. During testing, the watermarked images are subjected to scaling and cropping attacks. After mild scaling, linear correlation is 0.94, while severe cropping reduces it to 0.65. The MSE of a watermarked image without attacks is 0.0018, and the acceptable threshold is 0.0025. Answer the following with proper justification:

A) Is the watermarked image, prior to any attack, within the acceptable fidelity range? After applying mild scaling and severe cropping, does the watermark remain detectable? What do these results reveal about the system's robustness and imperceptibility?

B) Provide a visual representation of the fidelity region with the calculated radius, and illustrate the detection region with the detection threshold.

Answer:

A) Given MSE (no attack) = 0.0018 and maximum acceptable MSE = 0.0025. Since 0.0018 ≤ 0.0025, the watermarked image lies inside the region of acceptable fidelity (imperceptibility constraint satisfied).

Detection rule: correlation ≥ 0.90 → inside detection region

For mild rotation: correlation = 0.94 → 0.94 ≥ 0.90, so inside the detection region (detection succeeds).

For severe cropping: correlation = 0.65 → 0.65 < 0.90, so outside the detection region (detection fails).

Imperceptibility: MSE below the allowed limit, so embedding is acceptable.

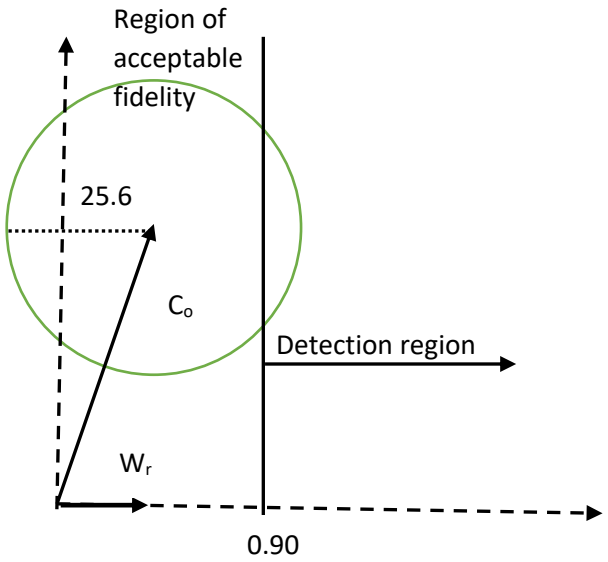
Robustness: Robust to mild geometric distortion (scaling): correlation remains above threshold (margin = 0.94 − 0.90 = 0.04). That small margin means the detector has modest tolerance to additional noise/variation. Not robust to severe cropping: correlation falls far below threshold (deficit = 0.65 − 0.90 = −0.25), so cropping destroys the template alignment/energy and the detector cannot reliably recover the watermark.

B) Region of acceptable fidelity is an N-dimensional sphere of radius $\sqrt{NT_{MSE}}$

N=512x512 = 262144

T_{MSE}=0.0025

Hence radius = 25.6



3. A watermarked 8-bit binary data sequence 10110110 is to be transmitted over a noisy channel. Use an appropriate error detection and correction technique to encode the data. If the MSB gets corrupted during the transmission(i.e., the most-significant bit gets inverted), demonstrate how the error can be detected and corrected at the receiver's end.

Answer:

Data sequence: 10110110 -> 8 bits

No. of parity bits = 4 (since 2^4 >= 8+4+1)

1	0	1	1		0	1	1		0		
				P8				P4		P2	P1

P1 -> determined by 01010 -> even number of 1s -> hence marked as 0

P2 -> determined by 01010 -> even number of 1s -> hence marked as 0

P4 -> determined by 1011 -> odd number of 1s -> hence marked as 1

P8 -> determined by 1011 -> odd number of 1s -> hence marked as 1

Encoded data: 101110111000

MSB changed data: 001110111000

P1 -> determined by 010100 -> even number of 1s -> hence marked as 0

P2 -> determined by 010100 -> even number of 1s -> hence marked as 0

P4 -> determined by 00111 -> odd number of 1s -> hence marked as 1

P8 -> determined by 00111 -> odd number of 1s -> hence marked as 1

Hence parity bits 1100 -> 12 in decimal. Hence error at bit in 12th position.

Flip the bit to 1. Hence, corrected data is : 10110110

4. Using the kernel K, compute the 4-point Discrete Cosine Transform of the image x. Embed the watermark W in the frequency domain using the LSB substitution technique, and display the resulting output in the frequency domain. Note: Do not round values in the intermediate steps.

$$K = \begin{bmatrix} 0.5 & 0.5 & 0.5 & 0.5 \\ 0.65 & 0.27 & -0.27 & -0.65 \\ 0.5 & -0.5 & -0.5 & 0.5 \\ 0.27 & -0.65 & 0.65 & -0.27 \end{bmatrix} \quad x = \begin{bmatrix} 2 & 4 & 4 & 2 \\ 4 & 6 & 8 & 3 \\ 2 & 8 & 4 & 4 \\ 3 & 8 & 6 & 2 \end{bmatrix} \quad W = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \end{bmatrix}$$

Answer:

$$\text{DCT} = K * x * K^T = \begin{bmatrix} 17.5 & 0.54 & -6.5 & 1.67 \\ -1.87 & -0.6844 & 1.49 & 1.795 \\ -2 & 0.65 & 0 & -0.54 \\ -1.92 & -0.53 & 1 & -2.43 \end{bmatrix} = F$$

$$\text{After LSB substitution of W in F: } \begin{bmatrix} 17.5 & 0.54 & -7.5 & 1.67 \\ -1.87 & -1.6844 & 1.49 & 1.795 \\ -3 & 0.65 & 1 & -0.54 \\ -1.92 & -1.53 & 1 & -3.43 \end{bmatrix}$$

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5. For a 4x4 image, Haar wavelet transform is applied, and multiplicative watermark embedding is performed on the vertical coefficients using a scaling factor, α=0.1 and a watermark matrix *W*. The resulting transformed matrix *M* is shown below, with the vertical coefficients highlighted in bold to indicate where the watermark has been embedded.

$$M = \begin{bmatrix} 32.5 & 27.5 & -17.5 & 12.5 \\ 50 & 32.5 & -10 & -2.5 \\ \mathbf{-2.75} & \mathbf{-6.75} & 7.5 & -12.5 \\ \mathbf{0} & \mathbf{-2.75} & -20 & 2.5 \end{bmatrix} \qquad W = \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$

Reconstruct the original cover image from the given information. Note: Use the Haar transform technique using averaging and differencing.

Answer:

$1+\alpha W = \begin{bmatrix} 1.1 & 0.9 \\ 0.9 & 1.1 \end{bmatrix}$

$H(1+\alpha W) = \begin{bmatrix} \mathbf{-2.75} & \mathbf{-6.75} \\ 0 & \mathbf{-2.75} \end{bmatrix} \Rightarrow H = \begin{bmatrix} -2.5 & -7.5 \\ 0 & -2.5 \end{bmatrix}$

$$H = \begin{bmatrix} 32.5 & 27.5 & -17.5 & 12.5 \\ 50 & 32.5 & -10 & -2.5 \\ \mathbf{-2.5} & \mathbf{-7.5} & 7.5 & -12.5 \\ \mathbf{0} & \mathbf{-2.5} & -20 & 2.5 \end{bmatrix}$$

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Reconstruction:

Row additions and subtractions:

$$\begin{bmatrix} 30 & 20 & -10 & 0 \\ 35 & 35 & -25 & 25 \\ 50 & 30 & -30 & 0 \\ 50 & 35 & 10 & -5 \end{bmatrix}$$

Column additions and subtractions:

$$Image = \begin{bmatrix} 20 & 40 & 20 & 20 \\ 10 & 60 & 60 & 10 \\ 20 & 80 & 30 & 30 \\ 60 & 40 & 30 & 40 \end{bmatrix}$$

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