LSB Steganography to Embed Creator's Watermark in Batik Digital Arts

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***Abstract*—This paper presents an implementation of Least Significant Bit (LSB) steganography to embed a hidden watermark in batik digital images. The goal of the technique is to provide a means of protecting the intellectual property of creators of batik digital arts while still allowing the images to be freely distributed and shared. The study demonstrates the effectiveness of the technique by showing that the embedded watermark is not visible to the human eye and does not significantly alter the quality of the image. The proposed technique uses the LSB method to embed a watermark in the binary data of the batik digital image. This method involves replacing the least significant bit of the image's pixel values with the bits of the watermark, thus altering the binary data of the image without causing noticeable changes in its visual appearance. The embedded watermark can only be detected by a decoding process, making it difficult to be removed or tampered with. The results of the study show that the implemented LSB steganography technique is successful in achieving its objective. The technique is able to effectively embed a hidden watermark in batik digital images without significantly altering the image quality or causing visual artifacts. This work highlights the potential of LSB steganography as a valuable tool for protecting the intellectual property of digital art creators, particularly in the field of batik images. Overall, this study contributes to the growing body of research on steganography and digital media protection. The successful implementation of the LSB steganography technique provides a promising approach for safeguarding the intellectual property of creators in the digital arts industry. Future research may explore other steganography techniques to address potential vulnerabilities and limitations of the LSB method.**

***Index Terms*—least significant bit (LSB), steganography, watermark, batik, digital, arts**

I. Introduction

Steganography is an ancient art of hiding messages in plain sight. In recent times, digital steganography has become popular as a means of hiding data within digital files such as images [1]–[4], videos [5]–[7], and audio [8]–[10]. Digital images can contain valuable information that requires protection, such as a creator's watermark, copyright notice, or other identifying information. However, the ease of digital copying and distribution poses a challenge to the protection of the creator's intellectual property rights. One approach to addressing this challenge is to use steganography techniques to embed a creator's watermark in the digital image [1].

Batik is a popular traditional Indonesian fabric that is well-known for its intricate patterns and rich cultural heritage. In recent years, batik has gained popularity as a digital art form, and many artists are creating batik-inspired digital images. However, the ease of digital copying and distribution of batik images poses a challenge to the protection of the creator's intellectual property rights. In fact, nowadays, it is rather easy to find batik images on the internet. One can simply enter keywords such as: "batik" or "batik pattern" on search engines, and a bunch of batik images will show up. However, it is rather difficult to discover the owner/creator of those batik images, even when we are intentionally trying to find them. Thus, digital batik arts become very vulnerable to the art-stealing practice. One can easily claim that one particular digital batik art is their own while, in fact, it is not.

Indeed, recent technology advancements such as encryption and blockchain (i.e., non-fungible tokens (NFT)) can increase the security of digital art ownership. Still, unless the original owner has registered the art by themselves, everyone can upload any batik art and claim it to be their own. Due to the NFT technology, the digital batik creator might even find difficulties in claiming their own digital arts if someone had illegitimately registered the corresponding digital arts without the creator's knowledge/intention. This issue can also apply to the conventional batik arts. For instance, one can easily obtain a batik in traditional forms (e.g., clothes), then digitalize that batik pattern (e.g., by using a camera/a scanner) and upload it to the web. Then, they can claim that the mentioned batik pattern is theirs. Considering that the majority of traditional batik artists are elderly and have no sufficient digital knowledge, this issue might become a serious problem.

One approach to addressing this challenge is to embed a creator's watermark in the batik digital image. Obviously, we cannot blatantly put the creator's watermark on top of the digital batik art since it will alter the visual of the batik itself and hence, deteriorates the batik's visual beauty. Thus, a simple and effective watermarking technique that does not alter the visual representation of the batik itself is needed. At this stage, steganography techniques might be an ideal solution.

In this paper, we propose a novel approach for embedding a creator's watermark in batik digital images using the Least Significant Bit (LSB) steganography. LSB steganography is a simple and widely used technique that involves replacing the least significant bits of pixel values in an image with the bits of the secret message [11]. LSB steganography works under the assumption that modifying a few least significant pixel values will not result in any visible changes. The proposed

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approach uses a combination of LSB steganography to enhance the security of the watermark and prevent unauthorized access.

The proposed approach is expected to provide an effective and robust solution for embedding a creator's watermark in batik digital images. The watermark can be used to protect the creator's intellectual property rights and provide a means for the creator to claim ownership of the image. Additionally, the proposed approach can also be used for other types of digital images, where it is necessary to embed a watermark to establish ownership or protect against unauthorized access.

LSB steganography has several advantages that make it a popular choice for embedding information in images. One of the main advantages is its simplicity [12]. LSB steganography involves replacing the least significant bit of each pixel in an image with a bit of the secret message. This process is straightforward and can be easily implemented using simple programming techniques. As a result, LSB steganography can be used by non-experts (e.g., batik artists) and is applicable in a wide range of contexts, including digital batik arts.

Another advantage of LSB steganography is its relatively low impact on image quality [11], [12]. The replacement of the least significant bit does not significantly affect the visual quality of the image. This means that LSB steganography can be used to embed information in images without being detected by the human eye. This makes it an effective technique for hiding sensitive information in plain sight. Furthermore, LSB steganography is compatible with a wide range of image formats [13]. The technique can be applied to various types of digital images, such as JPEG, PNG, and BMP. This makes it easy to apply LSB steganography in different contexts without the need for specialized software or hardware.

Indeed, LSB steganography is among the simplest steganography techniques and might be easily detected. Several studies have proposed LSB steganography detection techniques [1]. However, LSB steganography in our work is intended to be used to embed the creator's watermark and protect its intellectual property rights before the digital batik arts are available online. It does not matter when in the later stage, one detected and removed the creator's watermark from the digital batik since there will be other copies available online with the authors' watermark (and with the earlier upload date). Thus, digital batik ownership can always be preserved. In addition, in order to detect and remove the digital batik's watermark, one should be aware (or at least suspecting) that the steganography technique might have already been implemented.

The rest of the paper is organized as follows. Section II provides a brief overview of the previous studies related to the LSB steganography technique. In Section III, we describe the proposed LSB steganography approach for embedding a creator's watermark in batik digital images. In Section IV, we present experimental results to demonstrate the effectiveness of the proposed approach, followed by a brief discussion about the study limitations and the recommendations for future works in Section V. Finally, in Section 6, we conclude the paper with a summary of the contributions of our work and future research directions.

The primary contribution of this paper is the implementation of a novel approach for embedding a creator's watermark in batik digital images using LSB steganography. The proposed approach provides an effective and robust solution for protecting the creator's intellectual property rights and establishing ownership of the image. The approach is based on the widely used LSB steganography technique to embed the hidden watermark. The experimental results show that the proposed approach is effective in embedding the watermark in the batik digital image without affecting its visual quality.

In summary, the proposed approach can be used to embed a creator's watermark in digital images, including batik digital images, to protect the creator's intellectual property rights and establish ownership of the image. The approach provides an effective and robust solution for hiding the watermark within the image using LSB steganography and key-based encryption. The proposed approach is expected to be useful for protecting digital images and ensuring the integrity of digital content.

II. Previous Studies Related to LSB Steganography

Previous studies have explored various steganographic techniques and their applications. One of the most widely studied techniques is LSB steganography, which involves embedding information in the least significant bits of an image. A number of studies have examined the effectiveness and limitations of LSB steganography in different contexts.

In [14], the authors explained the LSB embedding technique and presented the evaluation results for 2,4,6 Least significant bits for a .png file and a .bmp file. The authors in [15] utilized Corner Filters, AES, and LSB Steganography to embed a secure message in 3D cover images. Further, in [16], the authors demonstrated an LSB steganography technique for text and image hiding. However, the authors conclude that further studies can be carried out to improve the image quality by increasing the peak signal-to-noise ratio (PSNR) value and reducing the mean square error (MSE) value. Another LSB application for digital images has been demonstrated in [17]. The authors employed the LSB steganography technique to secure the integrity of medical images. Other studies regarding the LSB steganography technique have been conducted in [18]–[20].

III. Proposed Technique: LSB Steganography

Least Significant Bit (LSB) steganography is a widely used technique for embedding data in digital images. This technique involves replacing the least significant bits of pixel values in an image with the bits of the secret message. LSB steganography is simple to implement and provides a high embedding capacity, which makes it suitable for a wide range of applications.

Compared to other steganography techniques, LSB steganography has several advantages. One advantage is that it is relatively easy to implement and does not require complex algorithms. Another advantage is that it provides a high embedding capacity, which means that a large amount of data can be hidden in a single image. Additionally, LSB steganography does not significantly affect the visual quality of the image, making it difficult for an observer to detect the presence of the hidden message.

In Fig. 1, we present the flowchart of a general LSB steganography technique. To illustrate the concept of LSB steganography, consider a simple example using binary bits. Suppose we have a binary message "1011" that we want to

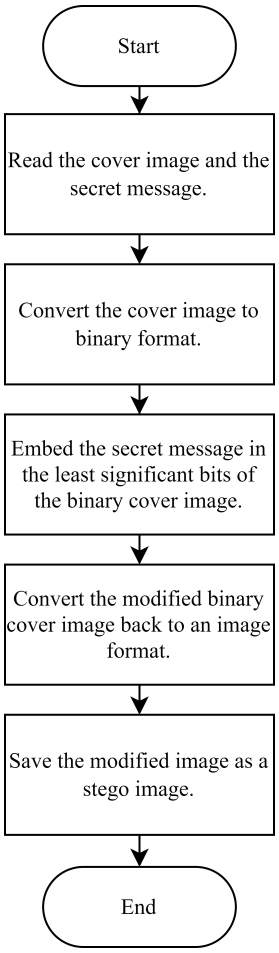

Fig. 1. Flowchart of a general LSB steganography technique.

embed in a grayscale image. Each pixel in the image can be represented by an 8-bit value, where the most significant bit represents the intensity level (0-255) and the remaining seven bits are unused. We can replace the least significant bit of each pixel with a bit from the message. For example, suppose the first four pixels in the image have values 10010010, 11001101, 11101011, and 10110001. We can embed the first four bits of the message in these pixels by replacing the least significant bit as follows: 10010011, 11001100, 11101010, and 10110000. The remaining bit of the message can be embedded in the next pixel, and so on, until all the bits in the message are embedded. The general concept of the LSB steganography algorithm is presented in Algorithm 1.

In our proposed approach, we use LSB steganography to embed a creator's watermark in batik digital images. The watermark is embedded in the least significant bits of the image pixels, which do not significantly affect the visual quality of the image. Additionally, to enhance the security of the watermark, we use key-based encryption to ensure that only authorized users can access the watermark. The proposed approach provides an effective and robust solution for embedding a creator's watermark in batik digital images, which can be used to protect the creator's intellectual property rights and establish ownership of the image.

IV. LSB Steganography Implementation on Batik Digital Arts

This section presents a simple example of LSB steganography implementation to embed a watermark to batik images.

Algorithm 1 LSB steganography algorithm.

Input:
Cover image
Secret message (in binary form)
Output:
Stego image
Procedure:

1: Convert the cover image to binary form.
2: Divide the secret message into binary data units.
3: For each data unit, extract the least significant bit (LSB) of a pixel value in the cover image.
4: Replace the LSB with the next bit of the data unit.
5: Repeat steps 3-4 until all the data units have been embedded in the cover image.
6: Convert the modified binary image back to its original format.

To embed a creator's watermark using LSB steganography, we followed the basic principle of the algorithm. Fig. 2 presents the step-by-step outline of the LSB steganography implementation proposed in this work. We first converted the batik image into a binary form to access each pixel's individual bits. We then divided the watermark message into binary data units.

Next, we embedded the watermark message into the binary form of the cover image using the LSB of the pixel values. We replaced the LSB of each pixel with the next bit of the watermark message. We repeated this process until all the data units of the watermark message were embedded in the cover image.

Once the watermark message was embedded, we converted the modified binary image back to its original format, in this case, a batik digital image. The resulting stego image appeared visually similar to the original batik image but with the embedded watermark message.

The LSB steganography technique is implemented using MATLAB software (code is available on the corresponding authors upon reasonable requests). In this work, the LSB steganography is conducted to embed a hidden watermark to a batik image in the .png format. Note that the implementation in this work is for illustration purpose, and thus, the embedded watermark does not necessarily means the creator's watermark. The batik image is obtained from [21] for illustrative purposes. As aforementioned, the batik image is in .png format and has the dimension of 208×360 pixels in 32-bit depth color. The watermark message is: "Batik Pattern from Kendal, Indonesia". This message is selected for no particular reasons other than for example purposes.

In Figs. 3-4, we present the batik image that we used in this work. Fig. 3 depicts the original image, while Fig. 4 depicts the batik image with the watermark message embedded in it. As observed, the watermark message was embedded in the batik digital image without significantly altering its visual appearance. In fact, there is no visual difference between the two figures, at least in human eyes' perceptances. Fig. 5 presents the command window of MATLAB. In this work, we divided the LSB steganography implementation into two stages. We insert the watermark in the embedding stage (i.e., "write" stage) and detect it in the watermark extraction stage (i.e., "read" stage). As in Fig. 5, the hidden watermark is embedded and retrieved successfully. This demonstrates the

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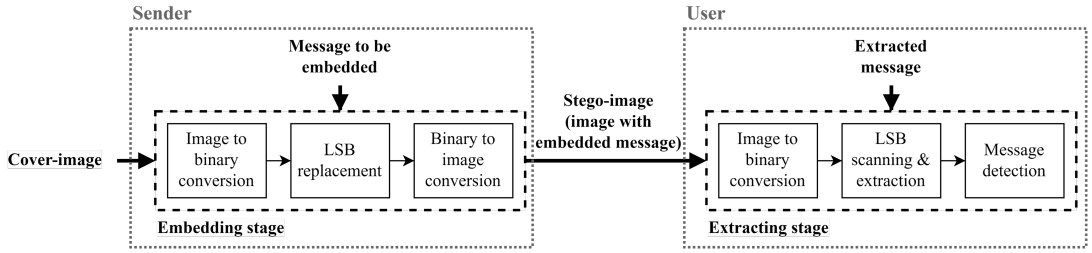

Fig. 2. The outline structure of image LSB steganography implemented in this work.

Fig. 3. Original batik image with no watermark. [21]

Fig. 4. Batik Image with embedded hidden watermark. [21]

```
Command Window
  >> write

  Watermark_to_be_embedded =

      'Batik Pattern from Kendal, Indonesia'

  >> read
  Detected Watermark:
  Batik Pattern from Kendal, Indonesia
fx >>
```

Fig. 5. MATLAB Command Window: "write" refers to the watermark embedding stage, and "read" refers to the watermark extraction stage.

potential of LSB steganography as a tool for protecting the intellectual property of batik artists and other digital media creators.

V. Study Limitations and Recommendations for Future Works

While our study has demonstrated the effectiveness of LSB steganography for embedding a creator's watermark in batik digital images, there are limitations that need to be acknowledged. In this section, we will discuss these limitations and provide recommendations for future works.

One limitation of our study is the lack of analysis on the robustness of the embedded watermark against various image processing attacks, such as compression, cropping, and scaling. While our implementation was successful in embedding the watermark in the cover image, the watermark may be vulnerable to these types of attacks, which could compromise its effectiveness. Future works could investigate the robustness of LSB steganography for watermarking in different image-processing scenarios.

LSB steganography is arguably among the simplest steganography techniques [22]. Thus, it is only natural that LSB steganography has numerous weaknesses. One of its weaknesses is its susceptibility to detection [1], [23]. As LSB steganography is one of the simplest steganographic techniques, it is relatively easy to detect and may not be suitable for high-security applications. Another weakness of LSB steganography is its low capacity [23], [24]. The amount of information that can be embedded in an image using LSB steganography is limited by the number of available LSBs. Therefore, LSB steganography may not be suitable for applications requiring large amounts of hidden data. LSB steganography is also sensitive to image compression [1], [24]. As it alters the least significant bits of an image, these bits are often the first to be discarded during compression. This means the embedded message may be lost or distorted when the image is compressed.

Moreover, LSB steganography is vulnerable to histogram analysis, statistical analysis, and visual inspection attacks [1], [23]. These attacks can reveal the embedded message's presence, making LSB steganography less effective for certain applications. Further, it is important to note that LSB steganography does not provide any protection against malicious attacks or attempts to tamper with the image [14], [25]. LSB steganography only provides a means of hiding information in an image. In the future, the implementation of more robust and more complex steganography techniques such as Spread Spectrum Steganography [3], Transform Domain Steganography [26], Least Significant Bit Matching (LSBM) Steganography [27], Pixel Indicator Steganography (PI) [28], and Palette-Based Steganography [29] for batik images can also be explored.

Another limitation of our study is the impact of the embedded watermark on the overall image quality of the digital batik art. While our implementation did not significantly alter the cover image's visual appearance, the stego image's quality may be affected by the embedded watermark. Future works could explore different embedding strategies and evaluate the quality of the resulting stego images.

Furthermore, our study only focused on embedding a single watermark message in a batik digital image. In practice, there may be multiple stakeholders involved in the creation and distribution of digital batik images, each with its own watermarking requirements. Future works could investigate the feasibility of using LSB steganography to embed multiple watermark messages in the same image without significantly degrading its visual quality.

Finally, our study was limited to batik digital images. Other

types of digital media, such as videos and audio recordings, may also benefit from the use of LSB steganography for watermarking. Future works could explore the potential of LSB steganography for embedding watermarks in different types of digital media.

To sum up, while our study has demonstrated the potential of LSB steganography for embedding a creator's watermark in batik digital images, there are limitations that need to be addressed. Future works could build on our study and investigate the robustness of the embedded watermark, the quality of the resulting stego images, and the feasibility of embedding multiple watermarks in the same image or in different types of digital media.

VI. Conclusion

Overall, this study has demonstrated the feasibility of using LSB steganography to embed a hidden watermark in batik digital images. The use of this technique provides a way to protect the intellectual property of the creators of batik digital arts, while still allowing the images to be shared and distributed freely. By embedding a watermark, creators can ensure that their work is properly attributed and recognized.

The implementation of LSB steganography in this study was successful in achieving its objective. The technique was found to be effective in hiding a watermark within the batik digital image without notably affecting the image quality. The result demonstrated that LSB steganography implementation did not alter the visual of the image and cannot be differentiated by human eye perceptance. Further, the results showed that the embedded watermark could only be detected by a decoding process, which makes it difficult to be removed or tampered with.

In conclusion, the results of this study demonstrate the potential of LSB steganography as a valuable tool for protecting the intellectual property of batik digital art creators. However, there are limitations to the LSB steganography technique, such as the vulnerability to attacks and the potential for information loss due to image processing (e.g., loose compression). Further research is needed to address these limitations and to explore other steganography techniques that may provide additional benefits. Nevertheless, the application of LSB steganography has significant potential for the digital arts industry (e.g., batik arts) and may be useful in other areas that require the protection of sensitive information in digital media.

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