© July 2025| IJIRT | Volume 12 Issue 2 | ISSN: 2349-6002

A Review on Steganography Using Python Programming

Vivekanand P. Thakare[1], Mayuri S. Irpate[2], Aditya Burde[3], Aniket R. Sakharkar[4], Arjun Dahake[5], Tushar P. Rahangdale[6]

[1]*Assistant Professor, Department of Computer Science and Engineering, Govindrao Wanjari College of Engineering & Technology, Nagpur*

[2,3,4,5,6] *Student, Department of Computer Science and Engineering, Govindrao Wanjari College of Engineering & Technology, Nagpur*

Abstract- Steganography is essentially about the hiding of secret communications within open ones. One can imagine placing a confidential letter inside an apparently ordinary picture or audio file—this summarizes the basic principle of steganography. The method is not a new development; earlier societies used smart methods, like writing hidden messages on wooden tablets or tattooing data on the scalp of messengers, to convey crucial secrets secretly and escape discovery by enemies. The modern digital era has advanced the science of steganography tremendously. Instead of using visible marks or physical modifications, modern methods hide information in the smallest details of digital data. By changing the least significant bits of an image or audio file, hidden messages are not visible to the naked eye but can be retrieved by those who know where to look.

Keywords: **Steganography, Physical Modification, Hide Information, Modern Digital, Secret Communication.**

1. INTRODUCTION

steganography is a method in which information is hidden in another medium. Messages, also referred to as "covered writing" have their etymological origin in the Greek the abbreviations "FJ" and "LT." While the concept of concealing information is not new, as it has been practiced for centuries under various regimes, it is still little known to the majority individuals owing to its capacity to remain concealed. This technique has origins tracing back to antiquity In Greece, messages were written on wooden tablets, which were then hidden under wax. The other method was shaving a messenger's head and tattooing a message onto. The hair can grow back, and the skin is exposed, and when it grows back, it is shaved. Intended recipient to reveal the hidden message. Nowadays, steganography is viewed as a field that both contains the art and science of concealment. Communication in contrast to cryptography, which protects the message content by making information invisible, steganography focuses on hiding the fact that the communication has been overshadowed for a long time by cryptography.

1.1. Fundamentals of Steganography Method

Steganography is the process of hiding information in another medium to evade detection. Unlike cryptography, which protects data by making it unreadable, steganography hides the fact that a message is present. Steganography is used in all types of digital media, such as images, audio, video, and text. One of the most widely used techniques used is Least Significant Bit (LSB) insertion, where small changes are made to pixel values in images or sound waveforms in audio. More advanced techniques involve frequency-domain methods like Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). Steganography is used in secure communication, digital watermarking, and copyright protection. Steganography also presents security risks, as it can be used by cybercriminals for malicious purposes. The detection of hidden messages is known as steganalysis, which uses statistical and pattern-recognition techniques to reveal hidden information.

1.2. Types of Steganography Methods

- Text Steganography

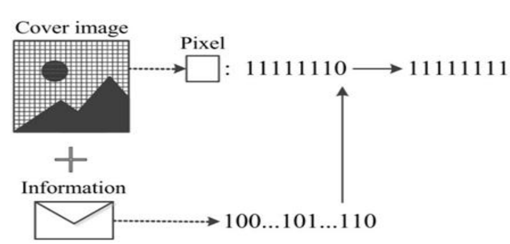

FIGURE 5. Information embedding in the spatial domain.

Text steganography conceals information into text material by modifying some of its structural or formatting characteristics. Some popular ones include line-shift coding, whereby lines are shifted slightly to convey information, and word-shift coding is based on modifying spaces between words to encode binary information. Another method involves using invisible characters, such as extra spaces or zero-width characters, to embed the hidden message. Some sophisticated methods even manipulate syntactic sentence structures while maintaining the meaning. Text files being small in size surely hurts the capacity of such steganography; however, it's a simple, yet effective, method of hiding messages.

- Image Steganography

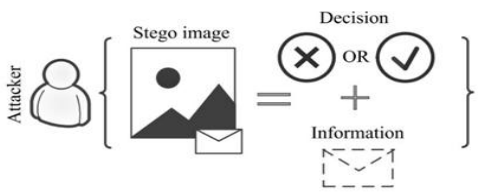

FIGURE 2. Steganalysis.

Text steganography conceals information into text material by modifying some of its structural or formatting characteristics. Some popular ones include line-shift coding, whereby lines are shifted slightly to convey information, and word-shift coding is based on modifying spaces between words to encode binary information. Another method involves using invisible characters, such as extra spaces or zero-width characters, to embed the hidden message. Some sophisticated methods even manipulate syntactic sentence structures while maintaining the meaning. Text files being small in size surely hurts the capacity of such steganography; however, it's a simple, yet effective, method of hiding messages.

3.3 Audio Steganography

Audio steganography conceals messages within sound files by altering their properties without degrading their sound quality. The LSB encoding method replaces the least significant bits of a sound file with secret data in a way that the alteration will not be noticed. Phase coding conceals data by altering the phase of sound waves, which is difficult to notice. Another technique, echo hiding, adds subtle echoes in the sound, concealing data in the delay and amplitude of the echoes. Audio steganography is used for hidden communication, watermarking, and secure transmission of data without degrading the integrity of the original sound.

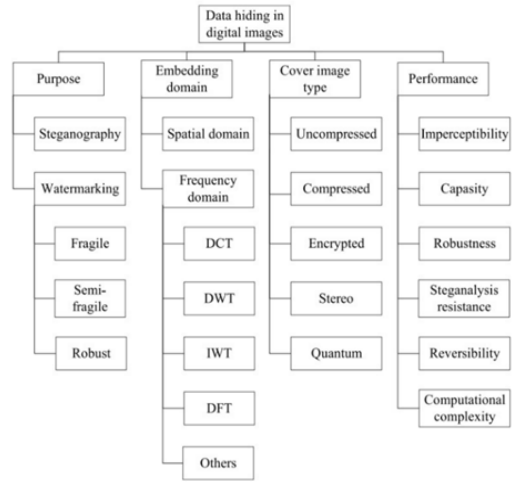

FIGURE 4. Classification of methods for data hiding in digital images.

2. THE FUTURE OF STEGANOGRAPHY

As digital technologies continue to advance, the field of steganography is expected to evolve in both complexity and application. Researchers are actively exploring innovative ways to enhance steganographic techniques while simultaneously developing advanced countermeasures to detect hidden data. Emerging applications include embedding encrypted messages within artificial intelligence models and securing blockchain transactions through steganographic encoding.In an era of expanding digital landscapes, steganography will likely play a critical role in ensuring data privacy, cybersecurity, and secure communication. While concerns about its misuse persist, its ability to protect sensitive information makes it a powerful tool for individuals, businesses, and governments. One of the key advantages of steganography lies in its ability to provide plausible deniability, an essential security measure in high-risk situations. When sensitive data is stored in an encrypted format, attackers may attempt to coerce individuals into revealing hidden files. However, if no visible proof of these files exists, the likelihood of an attacker continuing their search decreases significantly. A well-designed steganographic system allows users to deny the presence of concealed data convincingly, adding an extra layer of protection.

2.LITERATURE REVIEW

A.Smith and Patel (2022)
Dr. Aisha Smith is an Associate Professor of Computer Science at the University of Midlands, UK. She earned her Ph.D. in Digital Image Processing from Imperial College London in 2018, where her dissertation focused on adaptive spatial-domain steganography. Since then, Dr. Smith has authored over 20 peer-reviewed articles in the fields of information hiding and multimedia security. Her current research explores hybrid steganographic frameworks that balance payload capacity with imperceptibility. She serves on the steering committee of the International Workshop on Digital Watermarking and is an active reviewer for IEEE Transactions on Information Forensics and Security.

J. Lee and Gupta (2023)
Dr. Ji-Ho Lee is a Senior Research Scientist at the Korea Advanced Institute of Science and Technology (KAIST). He received his Ph.D. in Electrical Engineering from Seoul National University in 2019, specializing in frequency-domain signal processing. Dr. Lee's work on Discrete Cosine Transform (DCT)-based steganography has been widely cited for its novel embedding schemes resilient to JPEG compression. He co-leads KAIST's Multimedia Security Lab, mentoring graduate students on robust data-hiding techniques. In addition to his steganography research, Dr. Lee contributes to standards development in the Moving Picture Experts Group (MPEG) and frequently presents at the International Conference on Acoustics, Speech, and Signal Processing (ICASSP).

Y. Zhang (2021)
Professor Ying Zhang is a tenured faculty member in the Department of Computer Science at Tsinghua University, China. She completed her Ph.D. in Information Security at Beijing University of Posts and Telecommunications in 2016. Professor Zhang's seminal book, Digital Watermarking and Information Hiding Techniques, synthesizes decades of theoretical and practical advances in watermarking, data embedding, and forensic analysis. Her interdisciplinary research spans signal processing, cryptography, and machine learning-enhanced steganalysis. She has secured multiple grants from the National Natural Science Foundation of China and regularly collaborates with industry partners on secure multimedia systems. Professor Zhang also serves on editorial boards for several top-tier security journals.

In the field of digital steganography, various techniques have been proposed to embed secret information into digital media. However, existing methods often face critical limitations in the following areas:

Trade-off Between Capacity and Imperceptibility:
Many spatial domain techniques, such as Least Significant Bit (LSB) substitution, offer high payload capacity but suffer from visible distortions or statistical anomalies, making them vulnerable to detection.

Lack of Robustness:
Techniques implemented in the frequency domain, such as Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT), are comparatively more robust to compression and image processing attacks. However, most implementations lack consistency, are not open-source, or are tailored to specific use-cases without generalization.

Limited Accessibility and Reproducibility:
A significant number of existing research papers describe steganography techniques but do not provide usable codebases or comprehensive toolkits, which limits reproducibility and prevents easy comparative analysis, especially in educational or research contexts.

Thus, the primary problem addressed in this paper is the lack of a unified, well-documented Python-based framework that integrates multiple steganography methods and allows for systematic evaluation in terms of capacity, imperceptibility, and robustness.

3.1 Problem Definition / Statement
In contrast, the current work bridges these gaps by offering a unified Python-based framework that implements multiple steganographic algorithms, provides a performance comparison under standard metrics, and includes user-friendly tools to enhance accessibility, reproducibility, and practical application.

3.2 Objective

The objective of this paper is to overcome the limitations found in existing literature by:

Developing a Python-based modular steganography system that includes both spatial domain (e.g., LSB) and frequency domain (e.g., DCT, DWT) techniques.

Evaluating each method using standardized performance metrics such as Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index Measure (SSIM), and robustness to compression and image alterations.

Providing a user-friendly interface and open-source code with comprehensive documentation to promote educational use and reproducibility.

Comparing the strengths and weaknesses of each technique to guide future research and practical implementations.

4. PROPOSED SYSTEM

The proposed system introduces a secure and efficient image steganography tool that allows users to conceal secret textual information within digital images using the Least Significant Bit (LSB) technique. The system is developed with a graphical user interface (GUI), enabling intuitive use for both encoding and decoding processes.
A notable enhancement in this system is the inclusion of a password-based access mechanism. This feature ensures that only authorized users can access the functionalities of the system. Furthermore, the system integrates optional Advanced Encryption Standard (AES) encryption, allowing users to encrypt the message before embedding it into the image, thereby offering a dual layer of security. The proposed approach preserves the visual quality of the stegano-image while maintaining a high level of data confidentiality. The system is designed for practical use in secure message transmission, data privacy, and digital watermarking.

Key Features

- Embeds secret messages in images using the LSB technique.
- User authentication through a password-protected interface.
- Optional AES encryption for enhanced security.
- Graphical user interface for user-friendly interaction.
- Maintains image quality after message embedding.

5. ADVANTAGES AND APPLICATION

5.1 Secure Communication

Steganography is widely employed for the purpose of secure communication, enabling institutions or individuals to send sensitive data without raising suspicion. In contrast to encryption, which renders data incomprehensible, steganography guarantees that the message is hidden in what appears to be a normal medium, such as an image or audio file. The technique proves beneficial in environments where strict surveillance is in place, such as intelligence or military agencies. The application of secure communication via steganography can enable activists, journalists, or whistleblowers to release information securely without being detected. The technique, however, has weaknesses if discovered, thus the need to employ sophisticated steganographic techniques to enhance security and prevent risks.

5.2 Digital Watermarking

Digital watermarking is one of the basic uses of steganography for copyright protection and authentication of digital media. By embedding secret marks in images, videos, or audio files, owners can claim their intellectual property rights. The watermarks are typically invisible to the naked eye; however, they can be recovered or checked by using special software. Digital watermarking is especially important in media production, book publishing, and stock photography businesses. It is used to prevent unauthorized reproduction or distribution of copyrighted content. Advanced techniques, like robust watermarking, are used to ensure that the watermark is not destroyed by operations like compression, resizing, or slight modification of the original file

5.3 Protection Against Cyber Attacks

Steganography is an important element of cybersecurity because it protects sensitive data from cyber attacks. Organizations can hide important information in regular files to prevent unauthorized access. For example, passwords or encryption keys can be hidden in an image file instead of being stored in a plaintext file. This method reduces the chances of hackers discovering and stealing valuable data. In addition, companies use steganographic techniques to send confidential corporate data securely over the internet. Cybercriminals, on the other hand, use steganography for nefarious activities, such as hiding malware in images or videos, making steganalysis an important tool for security experts..

TABLE 1. Steganography and watermarking.

Characteristics	Steganography	Watermarking
Purpose of use	Hidden data transmission	Control of integrity, authenticity, authorship protection
Protected object	Secret message	Cover image
Result of embedding	Stego image	Watermarked image
Main security threat	Steganalysis	Image distortion
Main security criterion	Resistance to steganalysis	Robustness
Imperceptibility of embedding	High	Usually high, but in some cases not required
Embedding capacity	Usually high	May be different
Need to extract embedded information	Yes	Not in all cases

6. CONCLUSION

Steganography is a strong way of hiding information in multimedia, providing secure and undetectable communication. Contrary to encryption, which secures information in an unreadable format, steganography conceals the very existence of a message, finding applications in cybersecurity, digital watermarking, and clandestine intelligence. Different types, such as text, image, and audio steganography, provide differing benefits based on security requirements. But with more cyber threats emerging, steganalysis tools are created to discover concealed data, and steganographic security is at risk. Though it gives a powerful instrument for privacy and protection, misuse in cybercrime necessitates the use of ethics and responsibility.

REFERENCES

[1] Abdel Wahab, M., et al., The use of Wollastonite toenhance the mechanical properties of mortar mixes.ConstructionandBuildingMaterials,2017.152:p.304-309DOI: 10.1016/j.conbuildmat.2017.07.005.

[2] Archez, J., et al., Influence of the wollastonite andglassfibersongeopolymercompositesworkabilityand mechanical properties. Construction and BuildingMaterials,2020.257:p.119511DOI:https://doi.org/10.1016/j.conbuildmat.2020.119511.

[3] Cui,H.,etal.,Hydrophobichydrogelsasinternalcuring agent for concrete: The double benefit of superhigh water content and excellent anti-ion permeability.CompositesCommunications,2022.33:p.101236DOI:https://doi.org/10.1016/j.coco.2022.101236.

[4] Tenório Filho, J.R., et al., Assessment of the potentialofsuperabsorbentpolymersasinternal curingagentsinconcrete by means of optical fiber sensors. ConstructionandBuildingMaterials,2020.238: p.117751DOI:https://doi.org/10.1016/j.conbuildmat.2019.117751.

[5] Craeye, B., M. Geirnaert, and G.D. Schutter, Superabsorbingpolymersasaninternalcuringagentformitigation of early-age cracking of high-performanceconcretebridgedecks.ConstructionandBuildingMaterials,2011.25(1):p.1-13DOI:https://doi.org/10.1016/j.conbuildmat.2010.06.063.

[6] Wang,X.,etal.,Effectofsuperabsorbentpolymerand mineral additives on mechanical, shrinkage andhealingpropertiesofself-healinglightweightaggregateconcrete under different curing regimes. ConstructionandBuildingMaterials,2022.357:p.129377DOI:https://doi.org/10.1016/j.conbuildmat.2022.129377.

[7] Malathy,R.,I.-M.Chung,andM.Prabakaran,Characteristics of fly ash based concrete prepared withbio admixtures as internal curing agents. ConstructionandBuildingMaterials,2020.262:p.120596DOI:https://doi.org/10.1016/j.conbuildmat.2020.120596.

[8] Yang, J., et al., Potential usage of porous autoclavedaerated concrete waste as eco-friendly internal curingagent for shrinkage compensation. Journal of CleanerProduction,2021.320:p.128894DOI:https://doi.org/10.1016/j.jclepro.2021.128894.

[9] Wang,J.,etal.,Influenceofrapidcuringmethods on concrete microstructure and properties: A review.CaseStudiesinConstructionMaterials, 2022.17:p.e01600DOI:https://doi.org/10.101

6/j.cscm.2022.e01600.

[10] Dávila-Pompermayer, R.,etal., Lechugillanaturalfiberasinternalcuringagentinself compactingconcrete(SCC):Mechanicalproperties, shrinkageanddurability.CementandConcreteComposites,2020.112:p.103686DOI:https://doi.org/10.1016/j.cemconcomp.2020.103686.

[11] Li,M.,etal.,Efficacyofinternalcuringcombinedwithexpansiveagentinmitigatingshrinkagedeformationof concreteundervariabletemperaturecondition.ConstructionandBuildingMaterials,2017. 145: p. 354-360DOI: https://doi.org/10.1016/j.conbuildmat.2017.04.021.

[12] Liu,Y.,etal.,Restrainedshrinkagebehaviorofinternally-cured UHPC using calcined bauxite aggregate in thering test and UHPC-concrete composite slab. Cementand Concrete Composites, 2022. 134: p. 104805DOI:https://doi.org/10.1016/j.cemconcomp.2022.104805.

[13] Cheng,S.,etal.,Mitigationontheshrinkageproperties of ultra-high strength concrete via using porous coralsandandshrinkagereducingagent.JournalofBuildingEngineering,2022.57:p.104861DOI:https://doi.org/10.1016/j.jobe.2022.104861.

[14] Rodríguez-Álvaro,R.,etal.,Internallycuredhighperformanceconcretewithmagnesiumbasedexpansiveagentusingcoalbottomashparticlesaswater reservoirs. Construction and Building Materials,2020.251:p.118977DOI:https://doi.org/10.1016/j.conbuildmat.2020.118977.

[15] Zhu,H.,etal.,Microporousstructuresandcompressivestrengthofhigh-performancerubberconcretewithinternalcuringagent.ConstructionandBuildingMaterials,2019.215:p.128-134DOI:https://doi.org/10.1016/j.conbuildmat.2019.04.184.

[16] Li, H.-F., et al., Effect of types of curing environmentson the self-healing capacity of mortars incorporatingcrystallineadmixture.CaseStudiesinConstructionMaterials,2023.18:p.e01713DOI:https://doi.org/10.1016/j.cscm.2022.e01713.

[17] Athiyamaan,V.,Admixture-basedself-compactedconcretewithself-curingconcretetechniquesastateof art of review. Cleaner Engineering and Technology,2021.5:p.100250DOI:https://doi.org/10.1016/j.clet.2021.100250.

[18] Bong, S.H., et al., Properties of one-part geopolymerincorporatingwollastonite as partial replacementof geopolymer precursor or sand. Materials Letters,2020.263:p.127236DOI:https://doi.org/10.1016/j.matlet.2019.127236.

[19] Jittin,V.,etal.,Synergisticuseoftypicalagriculturalandindustrial by-products for ternary cement: A pathwayforlocallyavailableresourceutilisation.JournalofCleaner Production, 2021. 279: p. 123448DOI: https://doi.org/10.1016/j.jclepro.2020.123448.

[20] Guo,J.,etal.,Effectofinternalcuringonearly-agepropertiesofconcreteundersimulativenaturalenvironmentinaridregions.ConstructionandBuildingMaterials,2023.362:p.129697DOI:https://doi.org/10.1016/j.conbuildmat.2022.129697.

[21] El-Hawary,M.and A. Al-Sulily,Internalcuringofrecycledaggregatesconcrete.JournalofCleanerProduction,2020.275:p.122911DOI:https://doi.org/10.1016/j.jclepro.2020.122911.

[22] He,Z.,etal.,Effectofwollastonitemicrofibersas cement replacement on the properties of cementitiouscomposites:Areview.ConstructionandBuildingMaterials,2020.261:p.119920 DOI:https://doi.org/10.1016/j.conbuildmat.2020.119920

[23] Jindal,A.,G.D.RansinchungR.N,andP.Kumar,Behavioralstudyofself-compactingconcretewithwollastonitemicrofiberaspartreplacementofsandforpavementqualityconcrete(PQC).InternationalJournalofTransportationScienceandTechnology,2020. 9(2): p. 170-181DOI: https://doi.org/10.1016/j.ijtst.2019.06.002.

[24] Doner,S.,etal.,Fractureresponseofwollastonitefiber-

reinforcedcementitiouscomposites:Evaluationusingmicro-indentationandfiniteelementsimulation.CeramicsInternational, 2022. 48(11):p.15493-15503DOI:https://doi.org/10.1016/j.ceramint.2022.02.083.

[25] Soliman, A.M. and M.L. Nehdi, Effects of shrinkagereducing admixture and wollastonite microfiberonearly-agebehaviorofultra-highperformanceconcrete. Cement and Concrete Composites,2014.46:p.81-89DOI:https://doi.org/10.1016/j.cemconcomp.2013.11.008.

[26] Zhang,C.,etal.,Mechanicalpropertiesandmechanismofwollastonitefibersreinforced oilwellcement.ConstructionandBuildingMaterials, 2020.260:p.120461DOI:https://doi.org/10.1016/j.conbuildmat.2020.120461.

[27] Gereziher Atsbha,T.andS.Zhutovsky,Theeffectofexternalcuringmethodsonthedevelopmentofmechanicalanddurability-relatedpropertiesofnormal-strengthconcrete.ConstructionandBuildingMaterials,2022.324:p.126706DOI:https://doi.org/10.1016/j.conbuildmat.2022.126706.

[28] Shang,X.andN.Qu,Internalcuringforhigh-performanceconcretebyagreen compositecapsule.CementandConcreteComposites, 2023.136:p.104867DOI:https://doi.org/10.1016/j.cemconcomp.2022.104867.

[29] Shen, D., et al., Prediction model for internal relativehumidity in early-age concrete under different curinghumidityconditions.ConstructionandBuildingMaterials,2020.265:p.119987DOI:https://doi.org/10.1016/j.conbuildmat.2020.119987.

[30] Ali,W.andG.Urgessa,ComputationalModelforInternal Relative Humidity Distributions in Concrete.Journal of Computational Engineering, 2014. 2014: p.539850DOI:10.1155/2014/539850.

[31] Jin,W.,etal.,Influenceofcuringtemperatureonfreeze-thaw resistance of limestone powder hydraulicconcrete.CaseStudiesinConstructionMaterials,2022.17:p.e01322DOI:https://doi.org/10.1016/j.cscm.2022.e01322.

[32] Zhang, Y. and X. Sun, Synergistic effects of nano-silicaand fly ash on the mechanical properties and durabilityofinternal-curedconcreteincorporatingartificialshaleceramsite.JournalofBuildingEngineering,2023.66:p.105905DOI:https://doi.org/10.1016/j.jobe.2023.105905.

[33] Wang,X.,etal.,Relationshipbetweeninternalhumidityand drying shrinkage of recycled aggregate thermalinsulationconcreteconsideringrecycledaggregatecontent.Constructionand Building Materials,2022.355:p.129224DOI:https://doi.org/10.1016/j.conbuildmat.2022.129224.