Optimization of Perceptual Steganography Capacity Using the Human Visual System and Evolutionary Computation

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Dedication

I dedicate this to my parents Abdullah and Afnan for their endless support, sincere prayers and encouragements throughout my life and my PhD

I dedicate this to my husband Abdulrahman and my son Battal for their continuous love, sacrifices and patience throughout my years of study
اهداء

لحظات يقف فيها المرء حائرا عاجزا عن التعبير كما يختلط في صدره من تشкрат لأشخاص
أمدوه بالكثير و الكثير، لحظات صار لابد أن ينطق بها اللسان و يعترف بفضل الآخرين اتجاهه لأنهم و
بصراحة كانوا الأساس المتين الذي بني عليه صرح العلم و المعرفة لديه، و أناروا سبيل بلوغهما
فأهدي ثمرة جهدي التي طالما تمنيت إهدائها و تقديمها في أحق طبق

إلى التي حملتني وهنا على وهن، و قاست و تألمت لألمي، إلى من رعتني بطففها وحنانها و
سمعت طرب الليل من أجل، إلى أول كلمة نطق بها شفتاي أمي الغالية أفان.

إلى الذي عمل وكد و جد فقاس ثم غلب حتى وصلت إلى هذين إلى المصباح الذي لا يبخل إمادي
بالنور، إلى الذي علمني بسلوكه خصالا أعتز بها في حياتي والدي العزيز.

إلى شريك حياتي و توأم روحي الذي شجعني ببهبه و حنانه و دعمه الغير محدود على مواصلة مسيرتي
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إلى صغيري الذي كان دافعي و مصدر اصراري و قوتي، إلى ابني و فذة كيدي بثال

إلى رياحين حياتي في الشدة و الرخاء إخوتي وأسرتي جميعاً.

ثم إلى كل من علمني حرفاً أصبح سنا برقه يضيء الطريق أمامي.

وفي الأخير أشكر كل من ساهم في إنجاح هذه الرسالة من بعيد أو من قريب.
Originality Statement

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signed ..............................................................................

Date ......................................................................................
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Abstract

Efficient solutions for the purpose of delivery of information are called for by the revolution of internet. However concerns and problems over security, distribution of digital content and encapsulation of media artifacts have arisen as a result of these phenomenal developments. Hence, it has become necessary to seek capabilities to transport and secure multimedia with its meta-data in a safe way. Steganography has evolved as an enabler of multimedia applications keeping secret communication and embedded captioning secure.

There is a tolerable outcome that occurs between imperceptibility and steganographic capacity that fit right into the mix. For instance, the more subtle elements are hidden within the cover object having higher capacity, the more degradation is exhibited towards the carrier file, resulting in an increase in the distortion attributed to the information being concealed and at the same time, decreasing the stego file quality.

Suitable use of Evolutionary Algorithm and effective use of the weaknesses of Human Visual System in steganography are investigated in this thesis. Firstly, two high capacity steganography approaches are developed with the use of aforementioned features. The first method aims to overcome the limit capacity of edge based steganography in the spatial domain. The second method proposes a proper threshold selection for each coefficient which increase the capacity of transform domain. An estimate of the embedding rate based on image complexity is also proposed. Moreover, since peak signal-to-noise ratio (PSNR) is largely used as a measure of quality of images of stego, the reliability of current quality assessment metrics for stego images is also
evaluated at the third stage. Follow by developing an Anticipatory Quality Assessment Metric for effective imperceptibility measurement.

All proposed methods are aimed to assist the optimization of the statical and visual characteristics in the cover images while hiding large size of information. To reveal impressive imperceptibility and capacity of the proposed method over the existing dilemmas, a broad range of requirements have been carried out. To indicate the utility and value of all techniques proposed, they all have been empirically validated. The main aspects of image steganography are improved by the suggestions and methods, and are revealed by the results.
Nomenclature

AQAM  Anticipatory Quality Assessment Metric
BPCS  Bits Plan Complexity Structure
BPP   Bits per pixel
CSF   Contrast Sensitivity Function
DCT   Discrete Cosine Transform
DFT   Discrete Fourier Transform
DoG   Differences of Gaussian
DWT   Discrete Wavelet Transform
EA    Evolutionary Algorithm
EBE   Edges based data embedding method
GA    Genetic Algorithm
GP    Genetic Programming
HVS   Human Visual System
IQM   Image Quality Metric
JND   Just Noticeable Distortion
LOG   Laplacian of Gaussian
LSB  Least Significant Bits Substitution
LSBMR LSB Matching Revisited
MOS  Mean Opinion Scores
MSE  Mean Square Error
NVF  Noise Visibility Function
OPAP Optimal Pixel Adjustment Process
PLCC Pearson Linear Correlation Coefficient
PM1  Plus Minus 1 Algorithm
PSNR Peak Signal to Noise Ratio
PSO  Particle Swarm Optimization Algorithm
PVD  Pixel Value Differencing
ROI  Region of Interest
RPF  Random pixel embedding method
SDoG Summation of Differences of Gaussian
SQE  Subjective Quality Evaluation
SROCC Spearman Rank Order Correlation Coefficient
SSIM Structural Similarity Index
UIQI Universal Image Quality Index
WPM Watson’s Perceptual Model
wPSNR Weighted Peak Signal to Noise Ratio
Terms and Definitions

- **Steganography** is the science of concealing information within another non-secret information in an invisible way. It is derived from the Greek “steganos”, meaning 'covered'. Graphos is also Greek meaning 'writing'. Steganography mainly aims to hide the presence of the message.

- **Steganalysis** is the science of detecting hidden message using steganography.

- **Watermarking** is a pattern of bits inserted into a digital image, audio or video file that identifies the file’s copyright information (author, rights, etc.).

- **Cryptography** is the science of transforming information into an unreadable format.

- **Embedding/Insertion** is the process of mapping one file into another.

- **Extracting** is the process of obtaining the hidden message.

- **Cover-image/carrier** is the name of the original file that used to hide the message inside it.

- **Stego-image** is the name of the file after the embedding process. The cover image and the stego image must be identical.

- **Multi-dimensional media** is the integration of several types of media into one.

- **Encapsulation** is the process of packing multi-media into a single media.

- **Imperceptibility** is the quality of non perceptibility of the hidden file.

- **Capacity** is the number of allowable bits which can be inserted safely without any visible or statistical degradation.
• **Secret Message** is the name of the file or information that is hidden from general view.

• **Metadata** is a set of data that gives details about other data.

• **Optimization** is the process of enhancing and improving the stored results as best possible.

• **Fitness Function** is an objective measure of how close one is to a given solution.

• **Perception** is the ability of noticing something through the senses.
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