Image Compression Using Harmony Search Algorithm

Ryan Rey M. Daga and John Paul T. Yusiong

Division of Natural Sciences and Mathematics
University of the Philippines Visayas Tacloban College
Tacloban City, Leyte, 6500, Philippines

Abstract

Image compression techniques are important and useful in data storage and image transmission through the Internet. These techniques eliminate redundant information in an image which minimizes the physical space requirement of the image. Numerous types of image compression algorithms have been developed but the resulting image is still less than the optimal. The Harmony search algorithm (HSA), a meta-heuristic optimization algorithm inspired by the music improvisation process of musicians, was applied as the underlying algorithm for image compression. Experiment results show that it is feasible to use the harmony search algorithm as an algorithm for image compression. The HSA-based image compression technique was able to compress colored and grayscale images with minimal visual information loss.

Keywords: *Harmony Search Algorithm, Meta-heuristics, Image, Image Compression, RGB, PSNR*

1. Introduction

The advent of the Internet led to the phenomenal growth of the World Wide Web. Several websites containing web pages and multimedia applications were developed as a result. Developers include a number of images in designing websites to make these more appealing to the Internet users. However, incorporating numerous images in the design of the web pages caused the download time to increase dramatically. As a result, image compression techniques were utilized to minimize the negative outcomes of using images in the design of the web pages.

In the past few years, several types of image compression algorithms have been developed in response to the increasing amount of data involved. Image compression algorithms are widely used to store or transmit information by eliminating redundant information, thus minimizing the physical space requirement of the image [9].

Previous researches dealt with different optimization algorithms to compress images with minimal loss of information. Ant colony optimization, genetic algorithm and particle swarm optimization [1, 8-9] are among the optimization algorithms that were used as a technique for image compression.

In 2001, Geem *et al*. [5] developed an optimization algorithm called harmony search algorithm. The harmony search algorithm is a music-inspired algorithm that mimics the approach of musicians in searching for harmony when playing music. Also, previous researches have shown that the harmony search algorithm is able to solve optimization problems in different fields [5-6,10].

The paper is organized as follows. In Section 2, image and image compression algorithms that were developed will be discussed. The harmony search algorithm will be introduced in Section 3. Section 4 will discuss the proposed approach for image compression using the harmony search algorithm as the underlying algorithm while experimental results will be discussed in Section 5. Finally, conclusions are made in Section 6.

2. Image and Image Compression

An image is a two-dimensional object that resembles the appearance of the subject which is also referred to as the likeness seen or produced from something or somebody [7].

Images are classified into two types, namely, the vector image and the raster image. A vector image is made up of individual objects that are based on mathematical and geometrical properties with regards to its color and fill. This type of an image is able to maintain its quality in any given scale since it is resolution-independent [7]. On the other hand, a raster image, also referred to as a bitmap image, is composed of pixels that contain the information about the color to display. In this type of an image, the image quality may degrade when resized or displayed in another scale because it can only support certain resolutions, which makes it resolution-dependent [1]. In this research, raster images are given emphasis.

A raster image consists of an array of numbers, ranging from 0 to 255, which represents light intensities at various points. These points are referred to as pixels or picture elements and these pixels make up a raster image. The pixels in an image contribute to its file size. Each pixel uses 3 bytes to represent the primary colors: red, green, and blue (RGB). So, when transmitting raster images the file size becomes an important factor to consider and for this reason, utilizing image compression methods is beneficial to address this issue [2,8].

Image compression is very beneficial when transmitting images over the Internet and downloading images from Web pages. The main purpose of these methods is to minimize the file size of an image, in terms of bytes, without affecting the quality of the image. Reduction of the image's file size allows for a larger amount of data that can be stored in same amount of memory space and lesser amount of time required to download or upload an image [4]. Currently, several image compression methods have been developed and are available but the resulting image is still relatively less than optimal, thus, developing alternative image compression methods is still an area of research.

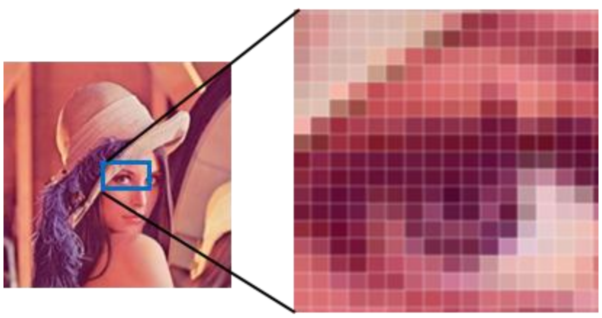


Fig. 1 A raster image

Image compression techniques are classified into two types, lossless compression and lossy compression. These two types of image compression techniques are differentiated based on the capability to recover the image when decompressed. Lossless compression is a type of image compression technique where no data is lost and it retains the full information needed to reconstruct the original image while lossy compression is another type of image compression technique where some information from the original image is permanently removed. In lossy compression, redundant information is eliminated from the original image which the users may not be aware of [2]. Since some data are permanently removed during process of compression, there may be a small degradation in the visual quality of an image.

Image compression techniques deal with certain color space to achieve image compression. One of the most commonly used color space is RGB. RGB stands for red, green, and blue components, which are the primary colors of light. This color space is widely used both in image processing and computer graphics. Basically, this color space is composed of three colors and all other colors can be obtained by combining these three colors. In the field of image processing, RGB represents the colors that each pixel in the image displays. The range of values in RGB color space is 0 to 255 [3].

3. Harmony Search Algorithm (HSA)

Several methods have been developed for many real-world problems and these methods focused on ways to increase efficiency and productivity by considering these problems as optimization problems. One approach in solving these optimization problems is by employing meta-heuristic methods. Meta-heuristic methods use some degree of randomness to search for an optimal solution, that is, these methods attempt to approximate the best solution to a problem using iterative trial-and-error approach. Some of the meta-heuristic methods are nature-inspired [5].

Previous researches used different approaches on image compression like the Ant Colony Optimization [9] algorithm, Genetic Algorithm [1] and Particle Swarm Optimization [8]. In this study, another approach using the harmony search algorithm will be used in image compression.

The link between playing music and finding an optimal solution led to the creation of the harmony search algorithm. It has been shown that finding harmony in music is analogous to finding an optimal solution in an optimization process. The harmony search algorithm, a music-inspired optimization algorithm, was first developed by Geem *et al.* in 2001 and whose effectiveness and efficiency has been shown in various researches [5-6,10].

When in search for the best harmony, a musician implements one of the three possible methods to come up with optimal elements: (1) playing from memory; (2) pitch adjustment; and (3) randomization. In 2001, Geem *et al*. [5] saw the similarities between the music improvisation processes and finding an optimal solution to hard problems. The researchers formalized the three methods as components of the optimization algorithm that was developed, the harmony search algorithm (HSA), and these components of the algorithm are the following: (1) harmony memory consideration; (2) pitch adjustment; and (3) randomization, which are also the main parameters of the algorithm [5-6].

The harmony search algorithm can be described in three main steps [5-6]:

1. **Initialization** - Program parameters are defined and the harmony memory is initialized with

random solutions; each solution is evaluated using an evaluation or objective function.

2. **Harmony improvisation** - A new solution is created. The three methods in the harmony search algorithm are used to decide what value will be assigned to each decision variable in the solution.
3. **Selection** - The best harmony or solution is selected when the termination condition is satisfied.

The pseudo-code of the harmony search algorithm is presented below [5-6] and is illustrated in Figure 2:

Begin
Define objective function $f(x)$, $x = (x_1, x_2 \ldots x_d)^T$
Define harmony memory consideration rate (r_{accept})
Define pitch adjustment rate (r_{pa}) and other parameters
Generate Harmony Memory (HM) with random harmonies
While *(t < max number of iterations)*
While *(i <= number of variables)*
If*(rand* $< r_{accept}$*)*
Choose a value from HM for the variable *i*
If*(rand* $< r_{pa}$*)*
Adjust the value by adding certain amount
End if
Else
Choose a Random Value
End if
End while
Accept the new harmony (solution) if better
End while
Find current best solution
End

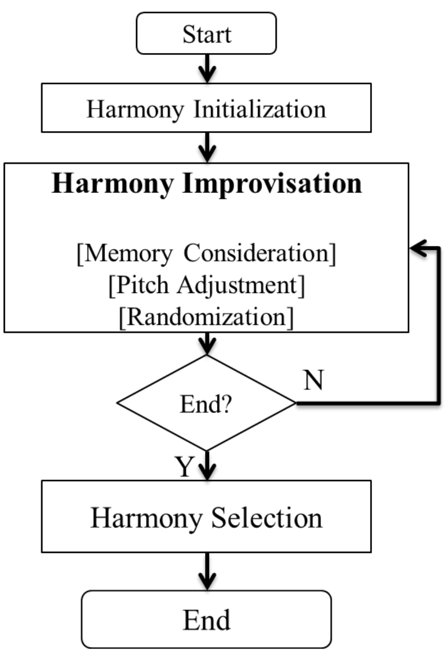


Fig. 2 Harmony search improvisation process

Before the optimization process starts, the following parameters of the HSA must be defined.

(1) **Maximum number of cycles –** the termination criterion of the optimization process.
(2) **Harmony memory size –** determines the number of solution to be stored in the harmony memory.
(3) **Memory consideration rate –** refers to the rate at which a solution from the memory is considered as a component in the new solution being created.
(4) **Pitch adjustment rate –** refers to the rate of adjusting a value from the harmony memory by adding a certain value.

4. Image Compression Technique using HSA

Figure 3 shows the general flow diagram of the proposed approach.

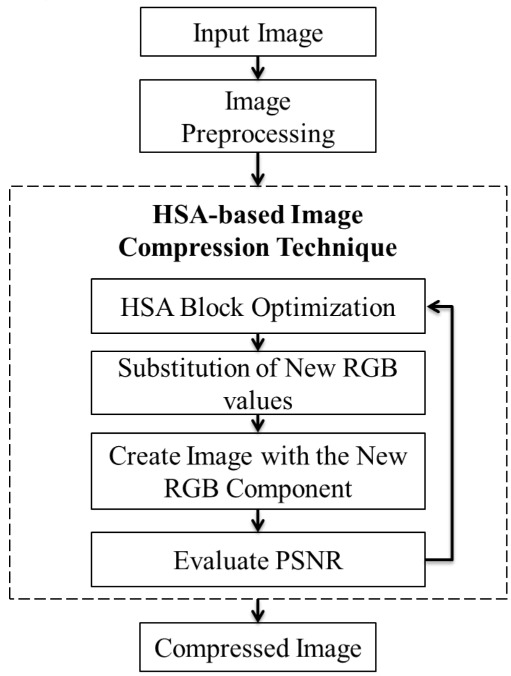


Fig. 3 HSA-based Image Compression

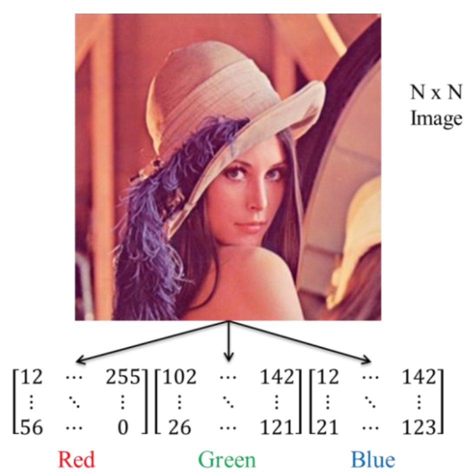


Fig. 4 The RGB components of an Image

4.1 Input

An N x N image J is decomposed into three N x N matrix where each matrix represents the Red, Green and Blue components (RGB components) of the image.

4.2 Variance-based Image Pre-processing

The variance σ^2 for each RGB component of the image J is calculated using Equation (1). For a set of values, a small variance implies lesser dispersion in the values. Hence, it is presumed that manipulating the RGB component of an image with the least variance would result to a compressed image with the minimal visual information loss [1]. Figure 5 illustrates the image pre-processing procedure using this approach. The selected RGB component is the component with the least variance.

$$\sigma^2 = \frac{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}(x_{ij}-\mu)^2}{n} \quad \textbf{(1)}$$

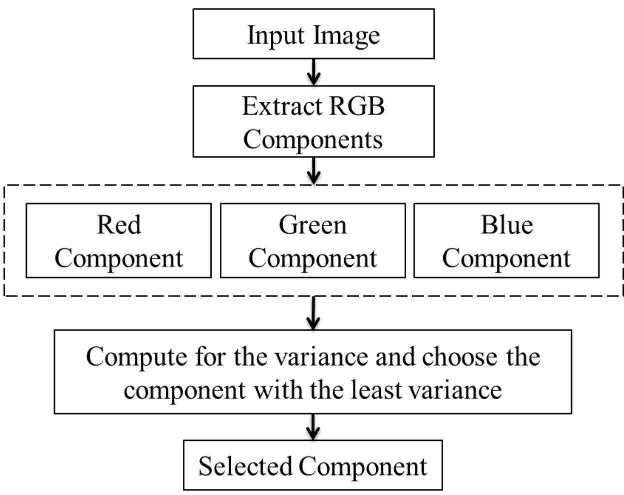


Fig.5 Variance-based Image Pre-processing

4.3HSA-based Image Compression

The harmony search algorithm will be employed as the underlying algorithm in this image compression technique. There are four major procedures that will be repeated until the termination criterion is satisfied. These procedures are the following: (1) HSA block optimization; (2) Substitution of new RGB values; (3) Creating an image with the new RGB component; and (4) Evaluation of the compressed image.

In HSA, when the termination criterion is satisfied, the best harmony (best solution) is determined. The best harmony contains the new RGB values for the selected RGB component. These new RGB values will be used to create the compressed image.

4.3.1 HSA Block Optimization

Given an n x n image, the harmony will have a dimension of $\frac{(n\,x\,n)}{4}$ where an element in the harmony represents a 2x2 pixel block of the selected RGB component. Each element in the harmony will be initialized with an RGB value ranging from 0 to 255. For a 4x4 image, the harmony will have four elements and is illustrated in Figure 6.

2	9	4	3

Fig. 6 A sample harmony for a 4x4 image

The HSA block optimization procedure attempts to optimize the selected RGB component without changing the RGB values of the other two RGB components. In this procedure, the original RGB values in each of the 2x2 pixel block of the selected RGB component will be substituted with the corresponding RGB values in the harmony and quality of the image produced using the said harmony will be evaluated using the Peak Signal-to-Noise Ratio (PSNR) function as described in Equation (2).

4.3.2 Substitution of New RGB Values

The harmony will be used to substitute for the original RGB values of the selected RGB component, that is, the values in the harmony correspond to the RGB values that will be used to replace each of the 2x2 pixel block in the image.

Using the harmony in Figure 6, the selected RGB component will have a new set of RGB values after performing block substitution as shown in Figure 7.

1	12	4	3
17	51	33	49
6	8	24	23
80	9	7	63

Original Component

⇨

2	2	9	9
2	2	9	9
4	4	3	3
4	4	3	3

New Component

Fig. 7 A sample block substitution

4.3.3 Create Image with the New RGB Component

After the new RGB component is derived, it will be used to create the compressed image. As shown in Figure 8, the new RGB component will be combined with the other two RGB components whose RGB values were unaffected in the HSA block optimization procedure.

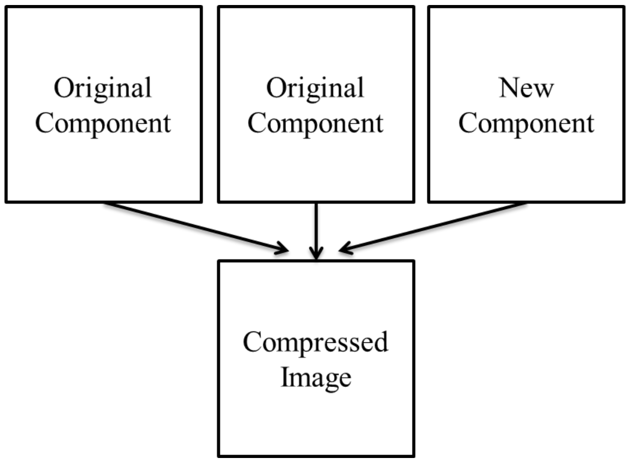


Fig. 8 Creating the compressed image

4.3.4 Evaluation Function: PSNR

The fitness of the harmony will be evaluated based on the quality of the image produced after incorporating the new RGB values of the selected RGB component to the image. The quality of the image will be evaluated using the Peak Signal-to-Noise Ratio (PSNR) as described in Equation (2), and is measured in decibels (dB). A high PSNR value indicates that there is less visual degradation in the compressed image.

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad \textbf{(2)}$$

The fitness of the newly generated harmony will be compared to the fitness of the other harmonies in the harmony memory. If the newly generated harmony obtains a higher PSNR value compared to the worst harmony in the harmony memory, then the worst harmony will be replaced by the newly generated harmony.

5. Experiment Results and Discussion

The goal of the experiments is to determine the efficiency of the harmony search algorithm as the underlying algorithm in image compression and evaluate its behavior using different types of images (colored and grayscale).

In this experimental setup, the following parameters are defined:

[1] Number of Cycles = 500
[2] Harmony Memory Size = 5
[3] Memory Consideration Rate = 0.95
[4] Pitch Adjustment Rate = 0.99

Table 1: Variance of each RGB component of the colored image

RGB Component	Red	Green	Blue
Variance	2405.05	2721.91	1155.30

Table 1 shows the variance of each of the RGB components of the colored image of Lena while Figure 9 shows the colored image of Lena that was used in the experiments.

The results of the experiments showed that manipulating the RGB component with the least variance produces an image with minimal visual degradation. As illustrated in Figure 10, the HSA-based Image Compression technique was able to produce a compressed image with better visual quality, as indicated by its PSNR, when manipulating the blue component of the colored image. The images produced when manipulating one of the RGB components of the colored image are shown in Figure 11.

Fig. 9 The colored image of Lena

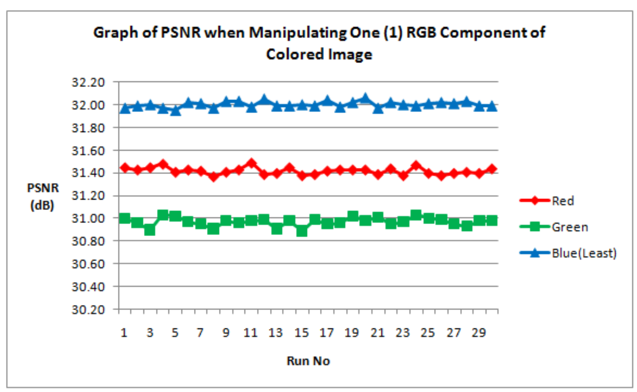


Fig. 10 The PSNR when Manipulating One RGB Component of the Colored Image

(a) Red Component (31.45 dB)

(b) Green Component (31.00 dB)

(c) Blue Component (31.97 dB)

Fig.11 The images created when manipulating one RGB component of the colored image

On the other hand, Figure 12 shows the grayscale image of Lena that was used in the experiments. Table 2 shows that the variance of the RGB components for the grayscale image of Lena are equal which suggests that each pixel in a grayscale image has the same RGB values for each of the RGB component. Upon examining the RGB values of the grayscale image, it has been found that these values are the same for each of the RGB component. Also, as depicted in Figure 13, the PSNR of the compressed image when manipulating any of the RGB components differed only by a small value. The images produced when manipulating one of the RGB components of the grayscale image are shown in Figure 14.

Table 2: Variance of each RGB component of the grayscale image

RGB Component	Red	Green	Blue
Variance	2255.99	2255.99	2255.99

Fig. 12 The grayscale image of Lena

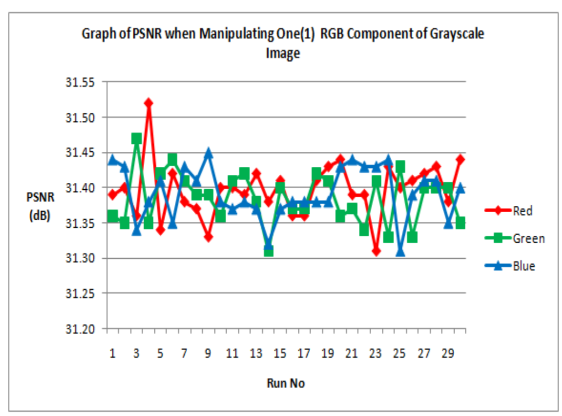


Fig. 13 The PSNR when Manipulating One RGB Component of the Grayscale Image

(a) Red Component (31.39 dB)

(b) Green Component (31.36 dB)

(c) Blue Component (31.44 dB)

Fig. 14 The images when manipulating one RGB component of grayscale image

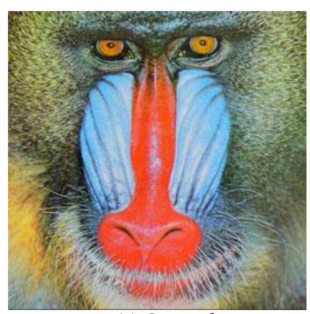
Other images like the pepper and mandrill where also used to test the effectiveness of the HSA-based image compression technique. In both the colored and grayscale versions of the images, the algorithm was able to compress the images with less visual degradation. Figure 15 shows the resulting images involving different colored images while Figure 16 shows the resulting images involving grayscale images.

(a) Original

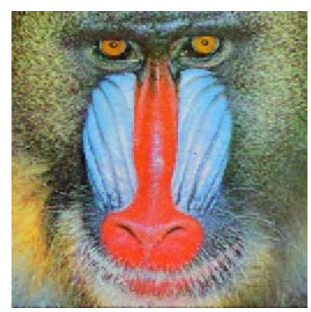
(b) Compressed (31.36 dB)

(c) Original

(d) Compressed (31.25 dB)



(e) Original



(f) Compressed (27.23 dB)

Fig. 15 Resulting images involving different colored images

Furthermore, the performance of the harmony search algorithm as the underlying algorithm for image compression was compared to another meta-heuristic algorithm, which was used for image compression, the Hybrid Particle Swarm Optimization (PSO)–Genetic Algorithm (GA) (Hybrid PSO-GA) [1].

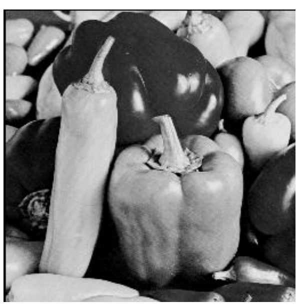
Experiment results show that the HSA was able to perform better when compared with the performance of the Hybrid PSO-GA since the HSA-based image compression approach was able to compress the image with lesser visual degradation indicated by a higher PSNR. Table 3 shows the PSNR values of the test images in relation to algorithms used for image compression.

Table 3: Comparison of HSA and Hybrid PSO-GA on different images

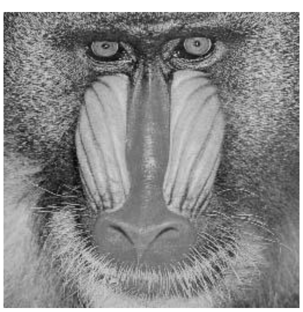
Image	Method	PSNR
Lena	HSA	31.97
	PSO-GA	27.24
Pepper	HSA	31.25
	PSO-GA	28.23
Mandrill	HSA	27.23
	PSO-GA	19.96


(a) Original


(b) Compressed (30.88 dB)


(c) Original


(d) Compressed (27.53 dB)


(e) Original

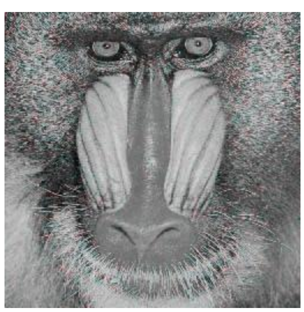

(f) Compressed (24.87 dB)

Fig. 16 Resulting images involving different grayscale images

6. Conclusions

Experiment results showed the feasibility of using the harmony search algorithm as an underlying algorithm for image compression. The HSA-based image compression technique was able to compress colored and grayscale images with minimal visual information loss.

In addition, when compared with the Hybrid PSO-GA approach to image compression, the HSA-based image compression technique was able to compress the image with lesser visual degradation as indicated by the higher PSNR values.

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