Review of Optimization Techniques for Digital Image Watermarking

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Abstract— Digital watermarking is an evolving field that requires continuous effort to find the best possible method in protecting multimedia content. Digital watermarking is the procedure whereby secret information (the watermark) is embedded into the host multimedia content, such that it is hidden, i.e., not perceptually visible. Besides this, information should be recoverable, even if content is degraded by different attacks. The two basic requirements for an effective watermarking scheme, imperceptibility (PSNR) and robustness (NCC), conflict with each other. For optimum PSNR and NCC, optimization techniques are used which includes Genetic algorithm, Hill and climb search, Tabu algorithm, Simulated Annealing etc. Here review of different optimization techniques for watermarking is presented.

Key words: Genetic Algorithm, Tabu algorithm, Hill climb search, Simulated annealing, Digital Image Watemarking, Optimization, PSNR, NCC

I. INTRODUCTION

The advancement in computer and networks technology had accelerated the prime importance for securing digital information [1]. The free access of digital media communication provides offenders huge opportunity to pirate copyrighted material. Hence, the need to use digital watermarking has significantly increases in order to detect and trace copyright violation. watermarking is an invisible signature embedded inside an image to show authenticity or proof of ownership. The watermarking solution promise to protect images by inserting text information and then tracking the images.

But, due to insertion of text or logo into images can degrade equality of original data. So, its tradeoff between data security and quality of data. So, Digital image Watermarking process can be viewed as an optimization problem due to existence of inversely related quality of data i.e. PSNR (Peak Signal to Noise Ratio) and data security i.e. NCC (Normalized correlation coefficient) parameters. PSNR value shows the extent of distortion introduced to the original host image due to watermark insertion and NCC specifies the degree of similarity between original watermark and extracted watermark. So, optimization techniques can be used to find best optimum values for PSNR & NCC. These are Genetic Algorithm, Hill climb search, Tabu search, Simulated annealing etc.

II. DIGITAL WATERMARKING

Basic model of Digital Image Watermarking consists of two parts: Watermark embedding & Watermark extraction[2].

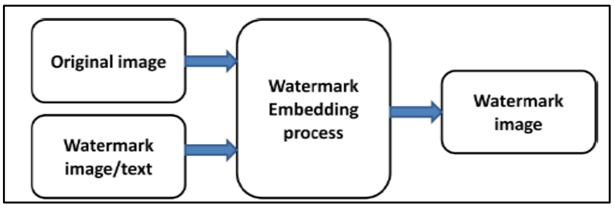

Fig. 1: Watermarking Embedding process

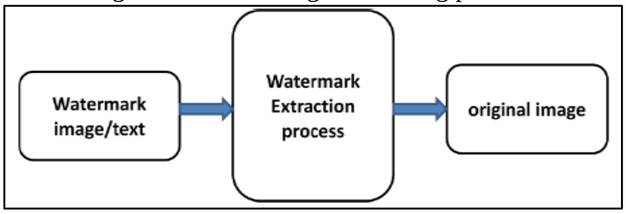

Fig. 2: Watermarking Extraction Process

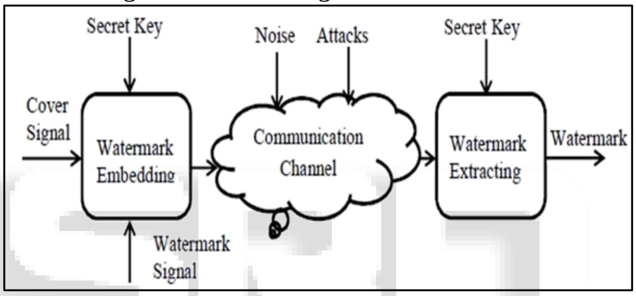

Fig. 3: Digital watermarking system

The information to be embedded in a signal is called a digital watermark, although in some contexts the phrase digital watermark means the difference between the watermarked signal and the cover signal. The signal where the watermark is to be embedded is called the *host* signal. A watermarking system is usually divided into three distinct steps, embedding, attack, and detection. In embedding, an algorithm accepts the host and the data to be embedded, and produces a watermarked signal.

Then the watermarked digital signal is transmitted or stored, usually transmitted to another person. If this person makes a modification, this is called an *attack*. While the modification may not be malicious, the term attack arises from copyright protection application, where third parties may attempt to remove the digital watermark through modification. There are many possible modifications, for example, lossy compression of the data (in which resolution is diminished), cropping an image or video, or intentionally adding noise.

Detection (often called extraction) is an algorithm which is applied to the attacked signal to attempt to extract the watermark from it. If the signal was unmodified during transmission, then the watermark still is present and it may be extracted[3].

III. NEED OF OPTIMIZATION

There are different algorithms in the spatial and transform domains for digital watermarking. The techniques in the spatial domain still have relatively low-bit capacity and are not resistant enough to lossy image compression and other image processing. For instance, a simple noise in the image may eliminate the watermark data. On the other hand, frequency domain-based techniques can embed bits for watermark and are robust to different attacks. Some transforms such as discrete cosine transform (DCT) and discrete wavelet transform (DWT) are used for watermarking in the frequency domain[4,5].

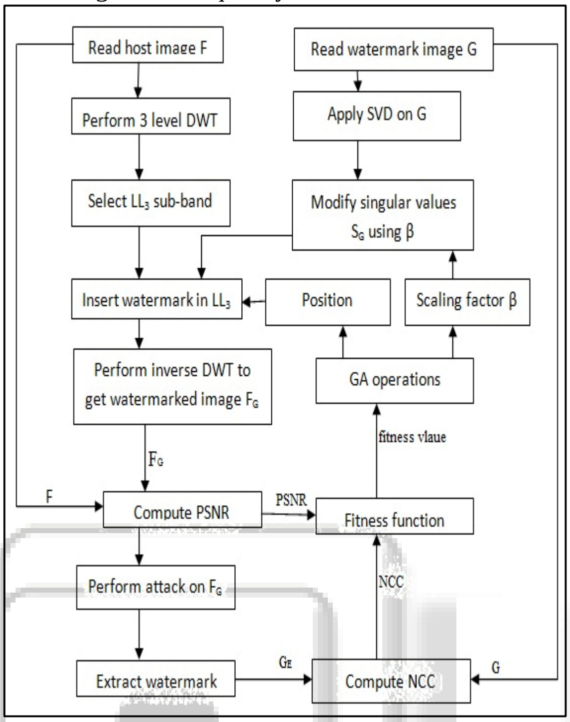

Fig. 4: Transform domain watermarking with Optimization techniques.

The common embedded and detect methods became well known, they were not only understood by their developers but also by their attackers. The attackers could always expose the weakness and discover the content of the original watermark message and attempt to destroy it. It is also observed that the quality of watermarked image is degraded when common embedding methods are used. If the above threat and problem is seen from another viewpoint, they could be considered as the motivation of developing good digital watermarking, which requires high quality image as well as robustness to attacks. Hence more advanced embedding and detection algorithms are being proposed.

Due to tradeoff between data security and quality of data Digital image Watermarking process can be viewed as an optimization problem due to existence of inversely related PSNR and NCC parameters[6,7]. In Transform domain, algorithms used for robust image watermarking includes Genetic Algorithm, Tabu search, Hill and Climb search etc, as optimization technique to find best optimum values for PSNR & NCC.

IV. Optimization Techniques

A. Genetic Algorithm

Genetic algorithm (GA) is a heuristic searching algorithm which is used for obtaining global maximum or tools available in the literature which mimic natural selection process [8]. fitness function of GA is formulated using PSNR & NCC and best watermarking system can provide optimum values of PSNR and NCC. The genetic algorithm process begins with randomly generated initial solution also known as initial population and an individual in the population is known as a chromosome which is consists of finite length binary strings. The quality of each chromosome in the population is evaluated using fitness function and those individuals having good fitness value are selected to produce next generation by using crossover and mutation operation. Selection, crossover mutation operations continuous looping until the best solution to optimization problem is found[14].

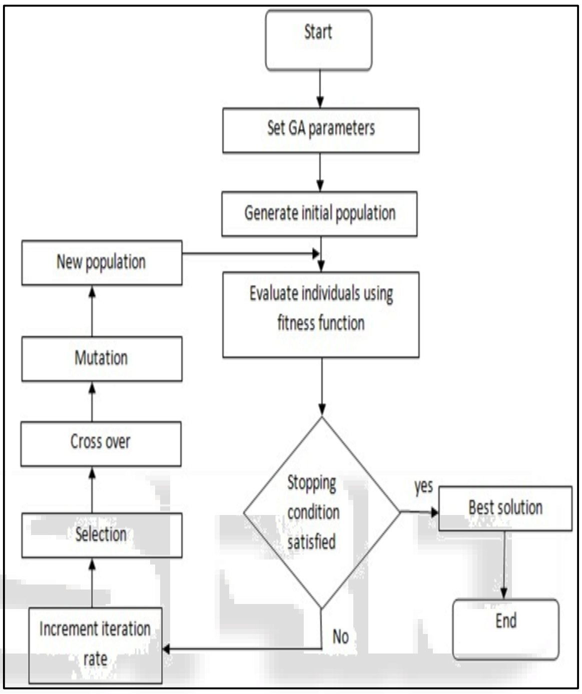

Fig. 5: Genetic Algorithm flow chart

1) *Genetic Algorithm Operation*

GA is used to search paramount position for watermark image embedding[10]. GA optimizes robustness and imperceptibility by searching best scaling factor β and finding a location for watermark embedding. It uses fitness function given in Equation to evaluate individuals in the population.

$$Fit\_func = PSNR + \mu * NCC. \qquad (1)$$

Therefore, fitness function of GA is formulated using these parameters and best watermarking system can provide optimum values of PSNR and NCC. **μ** is constant here usually 100.

B. *Hill Climb Search*

Hill climbing is a mathematical optimization technique which belongs to the family of local search. It is an iterative algorithm that starts with an arbitrary solution to a problem, then attempts to find a better solution by incrementally changing a single element of the solution. If the change produces a better solution, an incremental change is made to the new solution, repeating until no further improvements can be found.

Hill climbing attempts to maximize (or minimize) a target function $f(x)$, where x is a vector of continuous and/or discrete values. At each iteration, hill climbing will adjust a single element in x and determine whether the change improves the value of f(x). With hill climbing, any change that improves f(x) is accepted, and the process continues until no change can be found to improve the value of f(x). Then x is said to be "locally optimal".

Procedure- This is a variety of depth-first (generate - and - test) search. A feedback is used here to decide on the direction of motion in the search space. In the depth-first search, the test function will merely accept or reject a solution. But in hill climbing the test function is provided with a heuristic function which provides an estimate of how close a given state is to goal state[11].

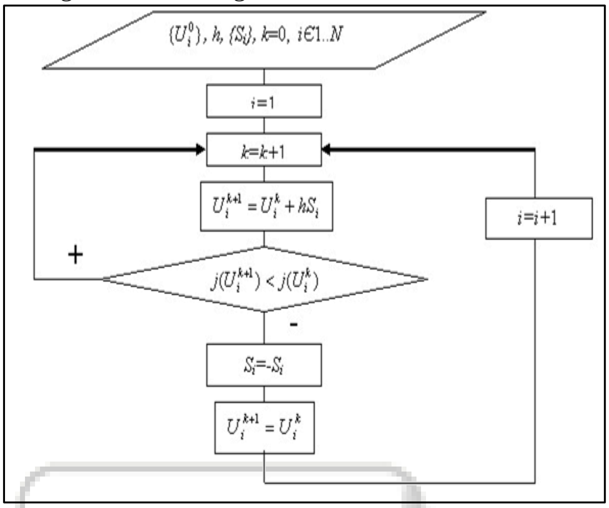

Fig. 6: Hill Climb Search Algorithm.

1) *Generate first proposed solution as done in depth-first procedure. See if it is a solution. If so quit, else continue.*
2) *From this solution generate new set of solutions use, some application rules*
3) *for each element of this set*
   – *Apply test function. It is a solution quit.*
   – *Else see whether it is closer to the goal state than the solution already generated. If yes, remember it else discard it.*
4) *Take the best element so far generated and use it as the next proposed solution.*
5) *This step corresponds to move through the problem space in the direction*
6) *Go back to step 2.*

C. Tabu Search

suppose that we are trying to minimize a function *f(S)* over some domain and we apply the so-called “best improvement” version of TS, i.e., the version in which one chooses at each iteration the best available move (this is the most commonly used version of TS)[12].

1) Notations

1) ***S***, the current solution,
2) ***S****, the best-known solution,
3) ***f****, value of *S**,
4) ***N(S)***, the neighborhood of *S*,
5) ***Ñ(S)***, the “admissible” subset of *N(S)* (i.e., non-tabu or allowed by aspiration).

2) Initialization

Choose (construct) an initial solution S_0.

Set $S := S_0$, $f^* := f(S_0)$, $S^* := S_0$, $T := Ø$.

3) Search

While termination criterion not satisfied do

1) *Select S in argmin [f(S')];*
   S'ε Ñ(S)
2) *if f(S) < f*, then set f* := f(S), S* := S;*
3) *record tabu for the current move in T (delete oldest entry if necessary);*

End while.

4) Termination criteria

In theory, the search could go on forever, unless the optimal value of the problem at hand is known beforehand. In practice, obviously, the search has to be stopped at some point. The most commonly used stopping criteria in TS are:

1) after a fixed number of iterations (or a fixed amount of CPU time);
2) after some number of iterations without an improvement in the objective function value (the criterion used in most implementations);
3) when the objective reaches a pre-specified threshold value.

In complex tabu schemes, the search is usually stopped after completing a sequence of *phases*, the duration of each phase being determined by one of the above criteria.

V. Simulated Annealing

Simulated annealing (SA) is a probabilistic technique for approximating the global optimum of a given function. Specifically, it is a metaheuristic to approximate global optimization in a large search space. It is often used when the search space is discrete (e.g., all tours that visit a given set of cities). For problems where finding an approximate global optimum is more important than finding a precise local optimum in a fixed amount of time, simulated annealing may be preferable to alternatives such as gradient descent.

Annealing, refers to the process which occurs when physical substances, such as metals, are raised to a high energy level (melted) and then gradually cooled until some solid state is reached. The goal of this process is to reach the lowest energy state. In this process physical substances usually move from higher energy states to lower ones if the cooling process is sufficiently slow, so minimization naturally occurs. Due to natural variability, however, there is some probability at each stage of the cooling process that a transition to a higher energy state will occur. As the energy state naturally declines, the probability of moving to a higher energy state decreases.]. In essence, simulated annealing draws an initial random point to start its search. From this point, the algorithm takes a step within a range predetermined by the user.

The following pseudocode presents the simulated annealing heuristic as described above. It starts from a state s0 and continues to either a maximum of kmax steps or until a state with an energy of emin or less is found. In the process, the call neighbour(s) should generate a randomly chosen neighbour of a given state s; the call random(0, 1) should pick and return a value in the range [0, 1], uniformly at random. The annealing schedule is defined by the call temperature(r), which should yield the temperature to use, given the fraction r of the time budget that has been expended so far[13].

1) Simulated annealing (SA) exploits an analogy between the way in which a metal cools and freezes into a minimum-energy crystalline structure (the annealing

process) and the search for a minimum [or maximum] in a more general system.
2) SA can avoid becoming trapped at local minima.
3) SA uses a random search that accepts changes that increase objective function f, as well as some that decrease it.
4) SA uses a control parameter T, which by analogy with the original application is known as the system "temperature."
5) T starts out high and gradually decreases toward 0.
6) A "bad" move from A to B is accepted with a probability P(moveA→B) = e(f (B) – f (A)) / T.
7) The higher the temperature, the more likely it is that a bad move can be made.
8) As T tends to zero, this probability tends to zero, and SA becomes more like hill climbing.
9) If T is lowered slowly enough, SA is complete and admissible.

1) Algorithm-

Let $s = s_0$.
For $k = 0$ *through* k_{max} *(exclusive):*
$T \leftarrow$ *temperature*(k / k_{max})
Pick a random neighbour, $s_{new} \leftarrow$ *neighbour(s)*
If $P(E(s), E(s_{new}), T) \geq random(0, 1)$*, move to the new state:*
$s \leftarrow s_{new}$
Output: the final state s.

VI. Conclusion

In this paper, we propose various optimization Techniques for watermarking scheme. Optimization techniques are used to find optimum values for PSNR & NCC. For best result combination of two or more method can be used. The Hybrid combination of Optimization techniques has advantages of robustness for its embedding data into all frequencies and large capacity in Watermarking so that best result can obtained.

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