Image Enhancement Using Nature Inspired Algorithms

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https://github.com/ashera1323/Image-Enhancement-using-Nature-Inpired-Algorithms

Millions of MRIs, CT scans and X-rays are taken every year, but not all of them are of high quality. Considering that it is not cheap and affordable in all countries, as well as adding to this the radiation received from the procedure, the question arises whether it is possible to improve the already obtained images without conducting additional studies at no cost.

In this article, we will analyze a three-part hybrid algorithm presented in 2013 by Pourya Hoseini to improve the contrast of images. The Hybrid Algorithm consist of: Ant Colony Optimization, Genetic Algorithms and Simulated Annealing algorithm. We tried to recreate this algorithm and apply it on real MRI images, and also used different combinations of these algorithms for comparison to find out why each of the algorithms is important and to convince that the combination gives the best result.

Keywords—MRI, CT, X-ray, Ant Colony Optimization(ACO), Genetic Algorithm GA, Simulated Annealing(SA), tumor.

I. INTRODUCTION

A. *X-ray and Conventional Radiography*

On November 8, 1895, the German physicist Wilhelm Roentgen who discovered the first X-ray, took the first x-ray scan of his wife's left hand, and thereby the biggest breakthrough in medicine in the entire existence of mankind [1]. Looking at the first x-ray, Wilhelm Roentgen saw the bone structure of the hand as clearly as his wife's ring Fig. 1.a. Never before in the history of medicine have people been able to look into the insides of a living person without a surgical autopsy. This discovery gave a huge impetus to the development of medicine and opened up new horizons.

One of the horizons become conventional radiography. For conventional radiography, an x-ray beam is generated and passed through a patient to a piece of film or a radiation detector, producing an image. Different soft tissues attenuate x-ray photons differently, depending on tissue density; the denser the tissue, the whiter (more radiopaque) the image. The range of densities, from most to least dense, is represented by metal (white, or radiopaque), bone cortex (less white), muscle and fluid (gray), fat (darker gray), and air or gas (black, or radiolucent)[2].

B. *Computed Tomography (CT) and Magnetic Resonance Imaging (MRI)*

Nearly 80 years later, the development of X-rays made it possible to discover Computed Tomography(CT). X-ray computed tomography (CT) is a medical imaging technique that provides images of the trans-axial planes (A horizontal plane; divides the body or any of its parts into upper and lower parts) of the human body. In comparison with a conventional radiograph, the CT image shows a much improved contrast. A CT image is reconstructed mathematically from a large number of one-dimensional projections of the chosen plane. These projections are acquired electronically using a linear array of solid-state detectors and an x-ray source that rotates around the patient[3].

Few years after on July 3, 1977, the first magnetic resonance imaging (MRI) exam on a live human patient was performed. MRI, which identifies atoms by how they behave in a magnetic field, has become an extremely useful non-invasive method for imagining internal bodily structures and diagnosing disease. The strong magnetic field created by the MRI scanner causes the atoms in your body to align in the same direction. Radio waves are then sent from the MRI machine and move these atoms out of the original position. As the radio waves are turned off, the atoms return to their original position and send back radio signals. These signals

Fig. 1.a. The first x-ray scan of hand.

are received by a computer and converted into an image of the part of the body being examined[4].

After the opportunity to look into patients in a non-invasive ways, as conventional radiography, CT and MRI, millions of images are taken annually to rule out diseases and make right diagnosis. Images are used to examine organs, tissues and skeletal system. Currently, the most popular areas of research are the central nervous system (brain and spine) and the musculoskeletal system. The

Fig. 1.b. A modern MRI scan of hand

test allows you to diagnose intracranial diseases such as: birth defects, inflammatory changes in the brain tissue, demyelinating diseases or cancer. In comparison with first x-ray scan Fig 1.a, modern MRI scan Fig 1.b is detailed and present us not only bones but also tendons, muscles, nerves, soft tissues and the complete structure of the joint with capsule, cartilage. Despite modern advances and all kinds of visualization, it is still difficult to read MRI images.

C. *Quality of scan*

There is three main issues that determines the quality of scans. First, it is the level of the equipment itself. The kind of "iron" in the hospital depends on how informative the pictures will be, which the doctor will analyze.

The second factor affecting the quality of an image study is the correct setting of the equipment when scanning a particular organ. It is not enough to have good hardware: it is important to set it up in such a way as to get informative pictures. During the study, the doctor deals with a certain set of programs, scanning modes of a particular organ. The modes include various parameters: the presence of certain pulse sequences (for example, T1-IP, T2-IP, DWI), the number of organ sections obtained, the thickness of the sections obtained, signal-to-noise ratio (SNR), spatial resolution (matrix), scanning plane, etc. In addition, qualitative research requires more time.

Thirdly, obtaining images of the organ of interest with the help of equipment is only the first stage of diagnostics. Equally, and even more important is the next stage - the interpretation of scan by a professional radiologist (or radiologist, in Western terms). The reliability of the diagnosis directly depends on how professionally and responsibly the doctor performs the analysis of the images.

Based on three factors of scan quality it is impossible to guarantee that in every medical center treatment will be done in the proper manner. Not every city or even country could afford the best equipment. On a level with this, the quality also depends on the setting and shutter speed. Many hospitals save on image exposure time, which also leads to poor quality images. Not all specialists are equally qualified, and in addition to the level of knowledge, everyone has different experience. It is impossible to get the knowledge that comes from experience.

To improve the quality of images without massive cost and increase them accurately, is to combine Hybrid Ant Colony Optimization, Genetic Algorithm, and Simulated Annealing to obtain new images. New enhanced images could help to fill the gaps of three main factors of quality of scans.

II. Related Work

The genetic algorithm(GA) is a global search method. It has the advantage of fast convergence, but as a disadvantage, it cannot use the feedback of the system and therefore has low efficiency in finding the exact best solution[5].

Ant colony optimization (ACO) is based on the natural deposition of pheromone trails and the attraction of ants when they are looking for food. It uses positive feedback to quickly find good solutions[6].

Simulated annealing (SA) results from heating and then slow cooling during metallurgical annealing. Although SA searches locally, at high temperatures it can choose the worst solutions to avoid a local optimum. SA has the property of global meta-heuristics.

Individually, each of these algorithms has its pros and cons. But combining these algorithms opens up new possibilities [5], [6], [7].

In May, 2013 Pourya Hoseini and Mahrokh G. Shayesteh proposed a hybrid algorithm which composed of three nature inspired algorithms: Genetic Algorithm (GA), Ant Colony Optimization (ACO) and Simulated Annealing (SA) meta-heuristics for increasing the contrast of images. In this way, the contrast enhancement is obtained by globally transformation of the input intensities. ACO is used to generate the transfer functions which map the input intensities to the output intensities. SA as a local search method is utilized to modify the transfer functions generated by ACO. GA has the responsibility of evolutionary process of ants' characteristics[8].

Based on the article, we use global contrast enhancement in the sense of transforming the intensity of grayscale images. Using a hybrid method, which is a combination of GA, ACO and SA, we will try to improve the MRI images for better visualization. According to an article that presents a new methodology where ACO generates transfer functions by moving ants. Characteristics and directions of movement of ants are set automatically by GA. This results in the GA usually influencing the search process as it can quickly find the correct global optimum. In addition, SA as a local search modifies and improves the transfer functions and pheromone trails generated by the ACO.

Based on the results that were shown in the article [8], it is acknowledge that in comparison with other techniques it works much better. In this article we try build the presented hybrid algorithm using python programming language and apply in real world usage by testing it on real MRI scans.

III. Methodology

Whole methodology that will be used below based on Pourya Hoseini and Mahrokh G. Shayesteh work which was presented earlier. Hybrid algorithm could be divided into three main parts: Ant Colony Optimization, Genetic Algorithm and Simulated Annealing.

Fig. 2 presents the flowchart of the hybridization strategy. As demonstrated, every individual in GA controls two ants in ACO. Ants produce transfer functions after that. In the SA phase, a certain number of the transfer functions from ACO's most recent run are randomly picked, and a small number of random points are selected from each transfer function.

SA then optimizes every chosen point and each of its neighbors for a specified number of cycles. By alternating between GA and SA iterations in an ACO experiment, hybridization is accomplished. In order to get the nearly optimal solution, GA must be performed numerous times in the early stages of the algorithm since it regulates the ACO and ant movement parameters.

In order to provide better results and to improve pheromone trails, SA as a local search is commonly used in the latter stages of the algorithm. Additionally, as SA progresses, more transfer functions, points of each transfer function that must be optimized, and cycles of the optimization process are run.

The halting condition for an algorithm run is a predetermined amount of ACO iterations in order to maintain a consistent processing time across algorithm runs for an image (we assumed 100).

A. Ant Colony Optimization (ACO)

The basic components of ACO, which effects ant's decision for moving are pheromone (dynamic evaluation value) and heuristic value (static evaluation value). ACO consist of two main stages: solution construction and pheromone update.

Generation of mapping functions is performed by ants' movement from some point to the top-right corner. The image is presented as matrix of numbers. The selection probability (P) for each neighbor point of ant is presented as:

$$P = \frac{(1+\tau_i)^{\alpha} \times ((1+(\frac{k_i}{\gamma})^{10}) \times \eta_i)^{\beta}}{\sum_{i \in G(i)} (1+\tau_i)^{\alpha} \times ((1+(\frac{k_i}{\gamma})^{10}) \times \eta_i)^{\beta}} \quad (1)$$

where the parameters α and β control the relative importance of pheromone trail against heuristic value. G(i) is the set of neighborhood points around ant. τ_i is the pheromone amount exists in a neighbor point. In order to avoid the zero probability in areas with no pheromone, the value 1 is added to τ_i . η_i is a heuristic value that for the neighbors of ant is set according to Fig.3. Also in (1), for up and right directions k_i and γ move to target are set.

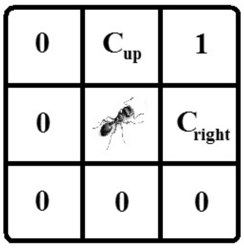

Fig. 3. Heuristic value of ant's neighborhood

After all ants move from the start point to the last point, SA modifies the recent pheromone trail and transfer functions of ants. Then the global pheromone update is performed.The parameters α, β, γ, C_{up}, and C_{right} are set by genetic algorithm.

B. Genetic Algorithm (GA)

Genetic algorithm is used in the hybrid algorithm for facilitating faster convergence of ACO. The fundamental parts of GA are encoding, selection, and reproduction. The five parameters of the ACO part (α, β, γ, C_{up}, and C_{right}) are encoded as a real coded chromosome with five genes. We consider 20 ants and total 10 chromosomes, where each chromosome is responsible for adjusting the parameters of the two ants. At the end of each generation, the individuals in the population copy their values to the parameters of the corresponding two ants. The ranges of α and β are from 0 to 5. γ varies between 100 and 250. The ranges of C_{up} and C_{right} are set from 0 to 3.

The roulette wheel method is used to choose parents. Two of the people are chosen to breed two offspring after all of them had their fitness levels assessed by the GA fitness function. The next generation is created when two new children take the place of the worst person and the weaker parent. The two worst individuals will be replaced by the two new children if the worst individual and the weaker parent are the same. This genetic algorithm is elitist since the process ensures the survival of the fittest. Reproduction stage is carried out by crossover and mutation operators. Uniform crossover is used with the probability of 0.85. Each offspring

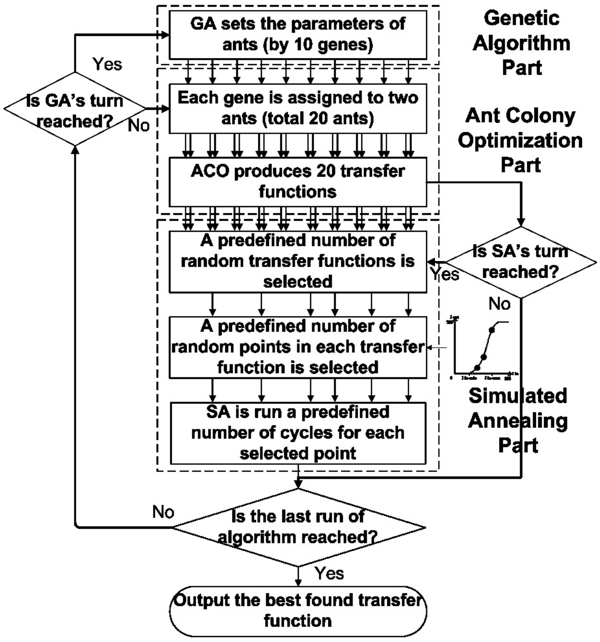

Fig. 2. Flowchart of hybrid algorithm

has mutation probability equal to 0.05. Utilized mutation operator just changes one gene of chromosomes with the restriction of -10% to 10% of the original value of that gene.

C. Simulated Annealing (SA)

The neighborhood definition, probability function, beginning temperature, and cooling schedule are crucial elements of the SA approach. In our study, SA optimizes the best transfer function discovered as well as a few additional transfer functions produced by the most recent ACO run. In the chosen transfer functions, random points are used as the beginning positions. In accordance with modifications made to the transfer function, the ant's pheromone trail is also altered in relation to its optimized transfer function.

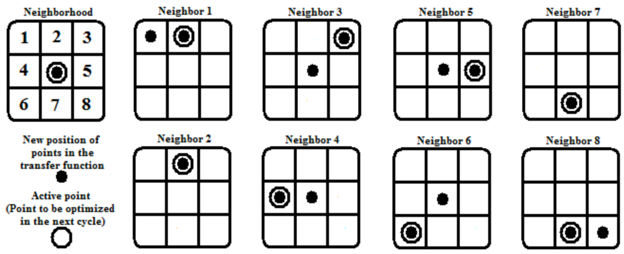

Fig. 4. Neighborhood of each point in SA and resulting action of choosing each of them.

The transfer function's neighborhood for each point is shown in Fig. 6, along with the selection of one of the neighbors that results. The active point (point to be optimized in the following cycle) is shown by a hollow circle, and the updated position of the current selected point or its nearby points is represented by a full circle. Keep in mind that only those neighbors are permitted in SA's neighborhood where the monotonically growing shape of transfer functions is retained. Additionally, if none of the potential neighbors of the current point are ultimately chosen (based on the probability function), the optimization of that point will be stopped (i.e. that point is a local optimum).

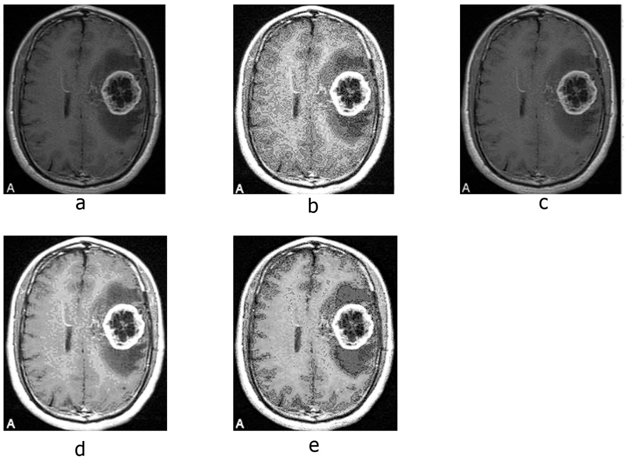

Fig. 5.2 Results of the enhancement techniques: a) Original b) Hybrid Algorithm c) Ant Colony Optimization d) Ant Colony Optimization + Genetic Algorithm e) Ant Colony Optimization + Simulated Annealing

IV. EXPERIMENTS AND EVALUATION

After the text edit has been completed, the paper is ready for the template. In the paper [8] efficiency of this algorithm was compared with another enhancement methods such as linear contrast stretching, histogram equalization, and fuzzy technique. And the observation gave that hybrid algorithm perform better.

Since the algorithm has been proven to perform better than other techniques, I decided to test how well the hybrid algorithm performs against to different combinations of Ant Colony Optimization with Genetic Algorithm and Simulated Annealing.

In order to evaluate the efficiency of the hybrid algorithm, we compared it to simple nature inspired algorithm ACO, ACO in combination with GA and ACO in combination with SA algorithm. As testing images was taken anonymous MRI scans of brain with tumor from dataset[9].

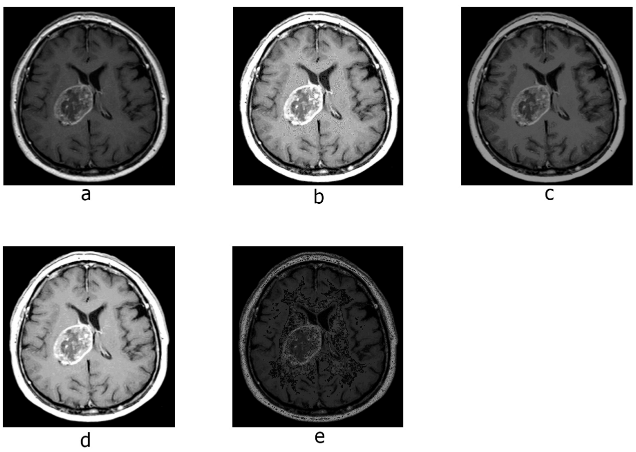

Fig. 5.1 Results of the enhancement techniques: a) Original b) Hybrid Algorithm c) Ant Colony Optimization d) Ant Colony Optimization + Genetic Algorithm e) Ant Colony Optimization + Simulated Annealing

V. ANALYSIS AND OBSERVATIONS

Correct reading of images is possible by an experienced radiologist. Immediately after graduation, a young specialist will not be able to correctly interpret the picture, since each person has individual anatomy features. Only over the years, the eye "learns" to distinguish the norm in the picture from the pathology. Image ratings depend on the quality of the image itself, factors such as Position, Intensity, Shape, Contours, Displacement play an important role.

In Fig 5.1, Fig 5.2 and Fig 5.3 given three different MRI scans in different techniques. On picture Fig 5.a we observe the original images. Original images could seem acceptable and easy to read. But after looking at image Fig 5.b which was enhanced using hybrid algorithms it become more understandable. We can observe clear edges and a brighter picture, which is important in assessing the tumor. However, let me note that the algorithm does not work perfectly in all cases, as for example in Fig 5.2 b.

The next picture that catches the eye is Fig 5.d. It is almost as distinct as the picture in Fig 5.b. Figure d uses ACO + GA but lacks some more detailization. Thus, we can clearly highlight the role of the SA algorithm, firing and changing the temperature helps to give the picture more details. Accordingly, in the figure e where CO + SA is used, we see how dark the whole picture has become.

In figures c and e where the genetic algorithm is not used, it can be seen that the figure lacks the same whiteness compared to the figures where the genetic algorithm is used.

The combination of these three algorithms really gives the best result. We can observe that every part is quite important. ACO is the main part of the whole algorithm by marking the most important areas, GA improves the picture by brightening the lighter areas and in combination with SA which gives more details by burning, we get a better picture.

VI. CONCLUSION

In this study, a proposed hybrid method for improving picture contrast was put to the test. The SA and ACO which have been proposed are employed in the overall image modification. The suggested GA aids in procedure automation. The enhanced criteria utilized in this work's fitness function yields good performance. It gives the altered images a detailed image. We examined the novel approach to various combinations of the methods Simulated Annealing, Ant Colony Optimization, and Genetic Algorithm. The outcomes show that from both subjective and objective perspectives, the new strategy works better than the aforementioned strategies. The novel technique may be used to enhance MRI, CT, and X-ray scan pictures without spending money on extra images and without exposure to more harmful radiation.

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