

Improving the Quality of Image Using Particle Swarm Optimization



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ABSTRACT

Image improvement is one of the important image processing capabilities. It can be used to transform one image to another to improve the view of it for human viewers, or to extract finer details of images which may provide better input for other automated image analysis systems. Image improvement is considered as an optimization problem. We can use particle swarm optimization (PSO) is used to solve it. The quality of the intensity image is improved by a transformation function, in which parameters are optimized by PSO based on given criterion function. For image improvement task, a transformation function is required which takes the intensity value of each pixel from the input image and generates a new intensity value for the corresponding pixel to produce the improved image. To evaluate the quality of the enhanced image automatically, a quality function is needed which tells about the quality of the improved image.

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INTRODUCTION

The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers, or to provide 'better' input for other automated image processing techniques i.e. the idea behind image enhancement is to bring out detail that is obscured, or simply to highlight certain features of interest in an image. But, unfortunately there is no general theory for determining what good image enhancement is when it comes to human perception. If it looks good, it is

good! However, when image enhancement techniques are used as pre-processing tools for other image processing techniques, then quantitative measures can determine which techniques are most appropriate [2].

Here, automatic image enhancement is considered as an optimization problem and Particle Swarm Optimization (PSO) is used to solve it as the PSO has ability to search a solution for parameters in a global space, and thus a relation between input and output gray levels is determined which convert an

original gray level image to an enhanced image with a good contrast. Image enhancement technique we implemented in this work requires parameter based transformation function which uses global information of the input image. PSO is used to optimize the value of these parameters on the basis of fitness value of the image which is defined by numbers of pixels in edge image, sum of edge pixels intensity and the entropy of the enhanced image i.e. resultant of the transformation function used.

The tool we use to solve the above discussed problem is MATLAB. Steps for work methodology are as follows.

1. For image enhancement a parameter based transformation function is used.
2. Initial fitness value is determined.
3. PSO is applied to optimize the parameter values so as to get large fitness value i.e. to get enhanced version of input image.

Particle Swarm Optimization

Particle Swarm Optimization was firstly introduced by Dr. Russell C. Eberhart and Dr. James Kennedy in 1995. As described by Eberhart and Kennedy [3], PSO algorithm is a population based search algorithm based on the simulation of the social behaviour of birds within a flock. The initial intent of the particle swarm concept was to graphically simulate the graceful and unpredictable choreography of a bird flock, with the aim of discovering patterns that govern the ability of birds to fly synchronously, and to suddenly change direction with a regrouping in an optimal formation. From this initial objective, the concept evolved into a simple and efficient optimization algorithm. In PSO, individuals, referred to as particles, are “flown” through hyper dimensional search space. Changes to the position of particles within the search space are based on the social psychological tendency of individuals to emulate the success of other Individuals. The changes to a particle within the swarm are therefore influenced by the experience, or knowledge, of its neighbours. The search behaviour

of a particle is thus affected by that of other particles within the swarm (PSO is therefore a kind of symbiotic cooperative algorithm). The consequence of modelling this social behaviour is that the search process is such that particles stochastically return toward previously successful regions in the search space.

Particle Swarm has two primary operators:

- Velocity update
- Position update

During each generation each particle is accelerated toward the particles previous best position and the global best position and new velocity value for each particle is calculated based on its current velocity, the distance from its previous best position, and the distance from the global best position. The new velocity value is then used to calculate the next position of the particle in the search space. The particle swarm algorithm is used here in terms of social cognitive behaviour. It is widely used for problem solving method in engineering.

In PSO, each potential solution is assigned a randomized velocity and is “flown” through the problem space. Each particle adjusts its flying according to its own flying experience and its companion’s flying experience. The i^{th} particle is represented as $\mathbf{X}_i = (x_{i1}, x_{i2}, \dots, x_{id})$. Each particle is treated as a point in a D-dimensional space. The best previous position (the best fitness value is called $pBest$) of any particle is recorded and represented as $\mathbf{P}_i = (p_{i1}, p_{i2}, \dots, p_{id})$. Another “best” value (called $gBest$) is recorded by all the particles in the population. This location is represented as $\mathbf{P}_g = (p_{g1}, p_{g2}, \dots, p_{gd})$. At each time step, the rate of the position changing velocity (accelerating) for particle i is represented as $\mathbf{V}_i = (v_{i1}, v_{i2}, \dots, v_{id})$. Each particle moves toward its $pBest$ and $gBest$ locations. The performance of each particle is measured according to a fitness function, which is related to the problem to be solved.

PSO Algorithm

Main steps for PSO algorithm is as follows:

- ✓ Initialize number of particles with random position and velocity.
- ✓ Evaluate the fitness value for each particle.
- ✓ Evaluate gbest.
- ✓ Evaluate pbest.
- ✓ Update velocity & position.
- ✓ Evaluate the fitness value for new position
- ✓ If condition is fulfilled gbest is the solution else repeat above steps

The procedure for PSO based image enhancement is shown below.

Repeat

```
for i = 1 to number of particles do
  if  $G(X_i) > G(pbest_i)$  then  $G()$  evaluates
  goodness
    for d = 1 to dimensions do
       $pbest_i = X_i$ 
    //  $pbest_i$  is the best state found so far
    end for
  end if

   $gbest = i$  // arbitrary
  for j = indexes of neighbours do
    if  $G(pbest_j) > G(gbest)$  then
       $gbest = j$ 

  //  $gbest$  is the index of the best performer in the
  // neighbourhood
  end if
end for

for d = 1 to number of dimensions do
   $V_i^t = f(X_i^{(t-1)}, V_i^{(t-1)}, pbest_i, gbest)$ 
  //Update velocity
   $V_i \in (-V_{max}, + V_{max})$ 
   $X_i^t = f(V_i^t, X_i^{t-1})$ 
  //Update position
end for
end for
  until stopping criteria
end procedure
```

The result of PSO algorithm for image enhancement is very much parameter dependent and fine tuning of these defined parameters is required in order to get the better result than other optimization algorithms. Parameter w used in equation plays an important role in balancing the global & local search and is known as inertia weight. Maximum and minimum value for this is set to two and zero respectively, which is same for all particles. It may have fixed value throughout the procedure but in our case we start with maximum inertia value i.e. 2 and gradually reduce it to minimum. Therefore, initially inertia component is large and explore larger area in the solution space, but gradually inertia component becomes small and exploit better solutions in the solution space. Inertia value w is calculated as follows:

$$w_t = (w_{max} - w_{min}) \times \frac{t}{t_{max}}$$

Where, t is the i^{th} iteration and t_{max} is the total number of iteration. Parameters c_1 & c_2 are positive acceleration constants, given a random number between 0 & 2. These parameters are fixed for each particle throughout its life. c_1 is also known as cognitive coefficient and it controls the pull to the personal best position while c_2 is known as social-rate coefficient and it control the pull to the global best position. r_1 called cognition random factor & r_2 called social learning random factor. These are random numbers in [0, 1] and varies for each component of the particles in every generation. These have important effect on balancing the global & local search.

The experiment proves that the four parameter to be optimized i.e. a, b, c & k give better results if there values are selected in the following range $a \in [0, 1.5]$; $b \in [0, (D/2)]$; $c \in [0, 1]$; $K \in [.5, 1.5]$

Matlab

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are

expressed in familiar mathematical notation. Typical uses include:

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or FORTRAN. The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects. Today, MATLAB engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computation. MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science.

In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis. MATLAB features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others. There are many built-in functions in MATLAB. The help command can be used to identify MATLAB

functions, and also how to use them. For example, typing help at the prompt in the Command Window will show a list of help topics that are groups of related functions. This is a very long list; the most elementary help topics appear at the beginning. For example, one of these is listed as matlab\elfun; it includes the elementary math functions. Another of the first help topics is matlab\ops, which shows the operators that can be used in expressions.

Implementation & Results

In order to evaluate the performance of proposed method we tested our method on many gray level and ultrasound images and compare the results of the proposed method in term of fitness value(F.V) with other enhancement techniques like linear contrast stretching (LCS) and histogram equalisation (HE). For performance measure we only consider the fitness value which is proportional to edgels, sum of edge pixel intensity and entropy which concludes higher the fitness value more is the enhancement of the image where P, T and W in Table 1 are referred as number of particle, number of iteration and window size respectively.

Table 1: Details of the original images & enhanced images

Image	P/T /W	Initial F.V	Lcs	He	Proposed Method
Ultrasound	10/5/5	0.98	1.53	1.88	2.086
Camera man	10/5/3	1.14	1.315	1.63	1.721
Couple	10/5/3	0.29	0.349	0.56	0.639
Lady	10/5/5	0.22	0.335	0.41	0.585

Figure 1, shows the original image of the ultrasound with initial fitness value 0.98 and figure 2 shows the enhanced version of the figure 1 with fitness value 2.086.

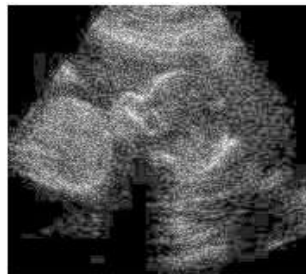
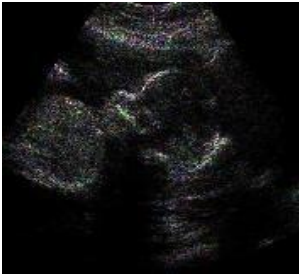


Figure 1: Original ultrasound image Figure 2 Enhanced ultrasound image

Figure 3 shows the original image of the cameraman with initial fitness value 1.14 and figure 4 shows the enhanced version of the figure 3 with fitness value 1.721.



Figure 3 Original cameraman image Figure 4 Enhanced cameraman image

Figure 5, shows the original image of the couple with initial fitness value 0.29 and figure 6 shows the enhanced version of the figure 5 with fitness value 0.639



Figure 5 Original couple image Figure 6 Enhanced couple image

Figure 7 shows the original image of the lady with initial fitness value 0.22 and figure 8 shows the enhanced version of the figure 8 with fitness value 0.585.



Figure 7 Original lady image

Figure 8 Enhanced lady image

We can see from the table 1 that the proposed method gives better results as compare to linear contrast stretching and histogram equalisation in term of fitness value.

Conclusion

Image enhancement is an optimization technique for improving the quality of dull image. It is the process of transform one image into another for enhancement of its view for human being. In this paper we perform Image improvement using Particle Swarm Optimization approach. The PSO technique optimizes the fitness value of a particle by evaluating the quality of image edges included in the picture with quality transformation function. Here improvement requires parameter based transformation function which uses global information of the image. Here an objective criterion for measuring image improvement is defined by edge numbers, edge intensity and the entropy value.

We have experimented our algorithm for gray scale images such as cameraman, couple and lady images. The result of our algorithm improves the quality of image with very high ratio.

For future scope we can improve the quality of image for RGB and other colour images.

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