MEDICAL IMAGE SEGMENTATION BY TRANSFERRING GROUND TRUTH SEGMENTATION BASED UPON TOP DOWN AND BOTTOM UP APPROACH

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ABSTRACT

In this paper, we present a novel method for image segmentation of the hip joint structure. The key idea is to transfer the ground truth segmentation from the database to the test image. The ground truth segmentation of MR images is done by medical experts. The process includes the top down approach which register the shape of the test image globally and locally with the database of train images. The goal of top down approach is to find the best train image for each of the local test image parts. The bottom up approach replaces the local test parts by best train image parts, and inverse transform the best train image parts to represent a test image by the mosaic of best train image parts. The ground truth segmentation is transferred from best train image parts to their corresponding location in the test image.

KEYWORDS

Shape matching, Hausdorff distance, affine transformation, Medical image segmentation, simulated annealing optimization

1. INTRODUCTION

Image segmentation is an essential topic in the field of the image processing. The segmentation is to highlight the object of interest in the image. The image segmentation provides the meaningful information about an object in an image which can be further used in the different application like face recognition, motion tracking and many more. As in the medical field, image segmentation plays an important role. The medical image segmentation is still a difficult problem due to poor contrast, noise and imaging artifacts. In the medical images, sometimes the boundaries of anatomical parts are not clearly visible. To obtain good segmentation of anatomical parts, various properties of images should be considered like intensity distribution, prior knowledge of shape.
In this paper, we solve the problem of segmentation of the hip joint structure in the MR images of the pelvic region of human. The abnormality of shape in the hip joint structure is called fermoacetublar impingement (FAI). The hip joint structure is the ball and socket joint. The ball is femur and socket is acetabulum. The abnormal shape of femur and acetabulum causes the lot of friction. Thus, the result is the damage of cartilage of femur or acetabulum in the hip joint [1] [2]. The FAI can be cured by medical surgery. For the treatment of FAI, medical practitioner

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performs the extraction of the hip joint manually. The boundaries of hip joint give the proper understanding of abnormality of structure.

Several techniques have been developed for medical image segmentation. The results are not accurate enough, so medical experts correct the results for medical surgery. In this paper, we propose the novel method to transfer the ground truth segmentation from the database to the MR image of another patient. The ground truth segmentation is manual segmentation done by the medical experts. The algorithm is based on the top down approach to match the test image globally and locally over the database images in order to find the best train image for each of the local part of test image. The bottom up approach assembles all the best train parts that are obtained from top down approach to represent the test image by the collection of train image parts. The ground truth segmentation is transferred from train image parts to test image at the respective location.

2. RELATED WORK

The different techniques have been developed for medical image segmentation over the years. The medical image segmentation has been difficult task due to poor contrast, noise, intensity variation and not clear understanding of boundaries of the parts in the image. The popular techniques for image segmentation are based on the intensity of the pixels. The pixel with similar gray scale values are considered as a region based upon the constraints. The region growing, merging and splitting methods are region based image segmentation [4]. The region growing method needs the initial seed point to start segmentation process. The method compares the initial seed point with other neighbouring pixels to merge into one region. This is an iterative process [4] [7]. The other techniques, the region merging and splitting are divided into two stages. First, the region splitting involves the decomposition of the image into a number of regions based on some criteria. Second part of the process involves the merging of decomposed parts. The merging of regions is the searching and aggregation process into similar regions [7]. As both methods have their advantages and disadvantages. As in [14], the region growing and region merging is combined for the ultrasound medical image segmentation. The combination of different approach like genetic algorithm, gradient based methods, wavelet processing, morphological methods with region growing and merging used for better initial condition to start the segmentation of medical image segmentation [13] [10].

The model based approach uses the prior knowledge for the segmentation of the object. The approach makes benefit of prior model to get the approximation of the object to be expected in the image. The top down strategy deform the model to fit with the data in the image. The model deformation is done by different methods. The active contour techniques so called snake uses energy minimization technique to deform the model [12]. The method is based on two energy function, internal and external energy. The internal energy keeps the closer to the prior model and gives smoothness to the curve. The external energy moves model towards salient features of image. The total energy is the summation of internal and external energy. The minimization of total energy results the segmentation of image. There is different version of snakes like gradient field snake [16], level set approach based on Mumford shah model [17]. The statistical model based on training set of shape that we want detect in the image. The training set consists of images of changing shapes that we want to detect in the image. The deformation of the model is obtained by the statistical properties of large number of shapes in the training set. The methods use only the shape constraint is called active shape model based segmentation [8] [9] [11] and the method uses the shape and image information like texture, salient feature is called active appearance model. The small training set of shapes causes the segmentation problems like holes in the final segment, over segmentation and many more.

In the field of medical image analysis, the object recognition and boundary detection of the organ in a medical image is very important to delineate their shape. For a proper segmentation, it is important to segment the local and global parts of the object. The top down approach gives a global detection and bottom up approach start from a low level and the results the object shape. Both the approach has their own importance, without the global detection, it is difficult to get proper local structural information. The prior model is used for searching the object in the image. The model is transformed to find similarity with objects in the image [3] [15]. After the global detection, the local structure matching is important to get acceptable segmentation. As in [6], the local part based template matching is used for human detection and segmentation.

The medical image segmentation is obtained from existing algorithms still corrected by the expert people. We develop the novel method to transfer the expert people segmentation by the shape matching algorithm based on the hausdorff distance to extract the boundaries of hip joint structure in the MR image of the pelvic region.

3. METHODOLOGY

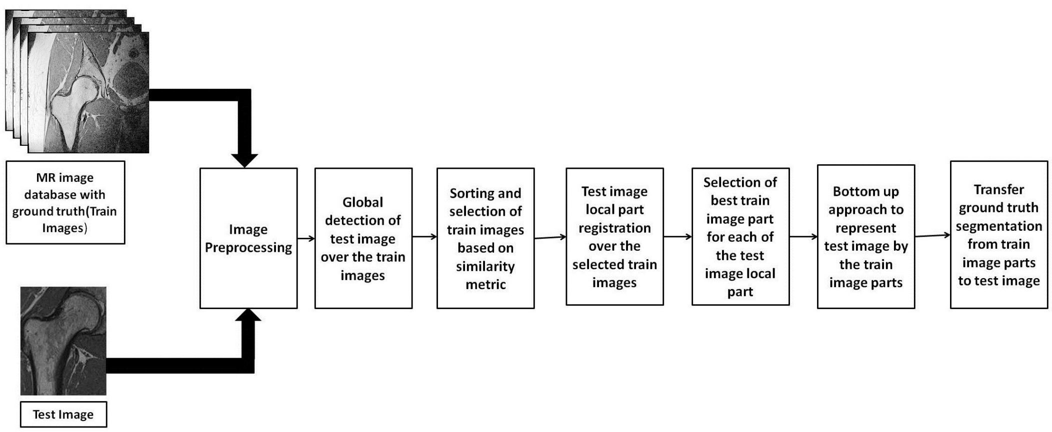


Figure 1: Workflow of the system

The method is the top down approach for shape matching based on the hausdorff distance of test image with train images and bottom up strategy to represent the test image from the collection of best train image parts. So, the ground truth segmentation can be transferred to test image.

3.1. Hausdorff distance

The hausdorff distance is the metric to measure the degree of mismatch between two shapes of images. The hausdorff distance is max-min distance between the two sets of points. To calculate the distance between two images, the boundaries are extracted from both test and train image. The edge image represents the set of points for test and train image. Given a test image A and train image B, the hausdorff distance is defined as

$$H(A,B) = \max(h(A,B), h(B,A))$$

Where

$$h(A,B) = max_{a \in A} \min_{b \in B} \|a - b\|$$

The $h(A,B)$ is the directed Hausdorff distance. It is defined as by considering every point of A, calculating the distance from that point to the closest point of B and evaluate the maximum among them [3]. The hausdorff distance is sensitive to the noise and outliers. The hausdorff distance is modified to fix this problem. The parts of shapes are compared. The directed partial hausdorff distance is defined as

$$h_k = K^{th}_{a\in A} \min_{b\in B} \|a-b\|,$$

Where $K^{th}_{a\in A}$ denotes the *K*th ranked value among the measured distances. The every point of A, calculate the distance from that point to the closest point of B and then points of B are sorted according to their distances and the *K*th value will indicate the *K* of the model point of A is within the distance of d with some points of A.

The partial hausdorff distance gives bad results with corrupted data; we need more a robust measure to solve the problem with corrupted data. The least trimmed square (LTS-HD) hausdorff distance is robust measure. It is defined by the linear combination of order statistics. LTS hausdorff distance is defined as

$$h_{LTS}(A,B) = \frac{1}{k}\sum_{i=0}^{k} min\|a-b\|\,(i)$$

Where k is $K=f.N$, the N is the number of points in the chunk of A. We used LTS-HD as a similarity metric to detect test image model in the database of train images [5].

3.2. Simulated annealing optimization

The simulated annealing is the search algorithm which finds the optimal solution in the search space. It is based on the probabilistic method to find the global optimum solution of the function in the given search space. The algorithm is influenced by the annealing process of the metal in the thermodynamics. The annealing process heats up the metal at high temperature to excite the molecules of the metal. At high temperature, it is possible to change the structure of the metal. The metal undergoes through the cooling process to obtain new physical structure. The temperature is reduced gradually to obtain the desired structure of the metal. The temperature is kept as a variable to simulate the heating and cooling process. The initial temperature and random solution are important parameters to start the algorithm [3]. When the algorithm is at high temperature, it will accept the more solution. This step will avoid the local optimum solution as it comes along the path of finding a global optimum solution. The temperature of the system is reduced gradually to work on the limited solution. The system can accept a worse solution, so algorithm concentrate on the search area where we can find the global optimum solution. The major advantage of the simulated annealing is not stuck in the local optima but search for the global optimum solution.

In our system, we have used the simulated annealing optimization to minimize the LTS hausdorff distance to detect the test image model in the train image dataset. The initial and final temperature is very important parameter to obtain desired solution.

3.3. Database of MR images

The segmentation of MR images is divided into three categories.1) Automatic 2) semi automatic 3) manual segmentation. The automatic segmentation is based on the intensity of the pixels in the image. The semi automatic segmentation needs human intervention to select the region of interest for segmentation. The human can recognize the boundaries and shape of the object of interest more accurately than the computer algorithm [1]. The manual segmentation is most accurate segmentation among all of them. We created a knowledge base of ground truth segmentation of MR images of hip joint structure. The MR images are segmented manually by the medical experts. The MR images are collected with their ground truth segmentation and then stored in the database. We used the database images knowledge to segment the MR image of other patients. The database images are named as train images. The knowledge $_1$base consists of 20 images.

4. TOP DOWN AND BOTTOM UP APPROACH

4.1. Global detection of test image

The main objective of top down approach is to detect global and local structure of the test image in the train images. In the hausdorff distance based shape matching is used for detection of the test image in a train image. The canny edge detection algorithm is used for the extraction of boundaries of both test and train images. Given a test image *M* and train image I_1 , I_2 .....I_n, the objective of shape matching is to obtain a transformation *T* to find similarity by the minimization of hausdorff distance as the similarity metric. The affine transformation maps the point in one plane to the other. The affine transformation parameter is scaling, rotation and translation. Let $p=(x, y)$ represents the point of test image, then the transformation is defined as

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix}, \quad \begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix}$$

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} S_x & 0 \\ 0 & S_y \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix}$$

Where S_x and S_y are the scaling parameters in x and y direction. The translation parameters are t_x and t_y in x and y direction and the rotation parameter either in a clockwise or anticlockwise direction. The transformed point (x_2, y_2) is close to the train image points. The simulated annealing search for best possible transformation in the given search space to minimize hausdorff distance to make test image more similar to the train image. The test image is registered with all the train images in the database. Then each of the registration gives the hausdorff distance and affine transformation parameters. The train images are sorted in the ascending order according to the hausdorff distance, half of the train images are selected from database for further processing. So, out of the 20 images only 10 images are selected.

4.2. Hierarchical tree based local part registration

As in the previous section, the train images are selected with their respective transformation parameters. The scaling and rotation is used for the transformation of the test image. Thus, the total number of transformed images is ten. Each of the transformed test images is decomposed into four parts as shown in figure 2. The hierarchical tree is constructed by placing decomposed parts into tree as shown in figure 2. The tree has three levels denoted by L_i, i= 0, 1, 2. Each level has transformed test image and decomposed for the next level like level 0 (L_0) which has only transformed test image. At each level, the local parts are registered with the selected train images. The train image is again sorted in ascending order according to the hausdorff distance obtain in registration process of local parts. The transformed test parts at the level 1 (L1) are denoted as Part 1, Part 2, Part 3, Part 4. Each of the tree nodes consists of 10 local parts. For example, Part_1 has 10 images and each of the Part_1 is registered with selected train image. The train images are sorted according to the hausdorff distance and first half of the train images are selected for their respective test image parts. For Part_1, the I_{10}, I_{13}, I_{14}, I_{15}, I_{16} is selected for next level registration. The transformation obtained in L_1 is used for next level registration.

The level 2 has 80 local parts. Each of the parts of level 1 is transformed and decomposed into four parts for the next level. The level 2 parts are represented as Part j_k. The j represents parts of level 1 and k represent the decomposition of level 1 part into level 2.So, Part 1_2 means Part1 of level1 is decomposed into four parts and it is the second decomposition of Part 1 of level 1.At level 2 (L_2) , the decomposed parts are registered with selected train images. For L_2, rotation and translation is used as transformation parameter for local part registration based on hausdorff distance. The train images for L_2 are sorted in ascending order according their respective hausdorff distance. The train image with lowest hausdorff distance is selected with their transformation as a best train image for its corresponding test image local part at level 2. Finally, each of the local part of level 2 are transformed and matched with their best train image. So, there are 16 local parts with their 16 best train images. We stop the decomposition of test image parts at level 2.

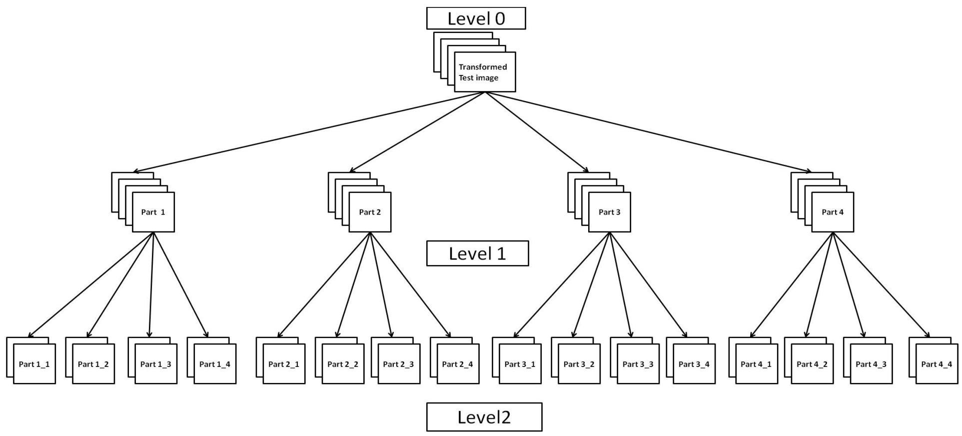


Figure 2: Top down approach of shape matching

4.3. Bottom up approach

The bottom up approach aggregates all best train image parts, and represent the test image from the collection of best train image parts. As in the previous section, each of the local part has their corresponding best train image. For each of the local part of test images, train image part is cropped to the same size of test image local parts at L_2. The local test image parts of L_2 are replaced by the corresponding train image part. The transformation obtained after the level 2 local part registrations is inversed and applied to the best train image part. The level 2 consists of best train image parts which are transformed inversely. The inverse scaling parameters are $1/S_x$ and $1/S_y$ in x and y direction. The inverse rotation is negative of angle of rotation; if the top down parameter is clock wise then inverse rotation is anti-clockwise. The $-t_x$ and t_y is the inverse translation in x and y direction. As we climb up the tree, at every level, we merge the best train parts into one region and as we can see in the figure 3, the final image is the mosaic of best train image parts.

The test image is symbolized by the collection of best train image parts. The database consists of ground truth of these train images. The ground truth segmentation from the train image parts of the test image to their corresponding location. Finally, the segmentation of test image is the collection of the ground truth segmentation of train images.

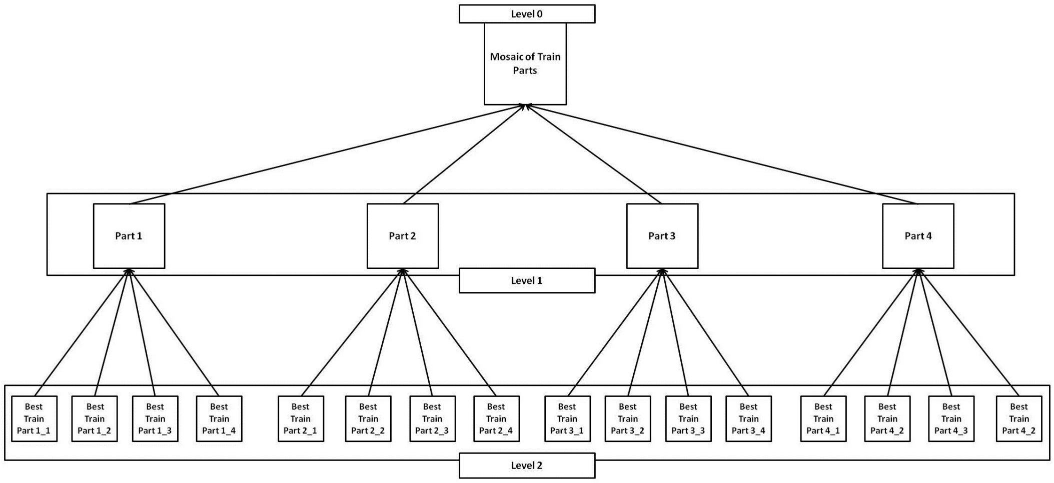
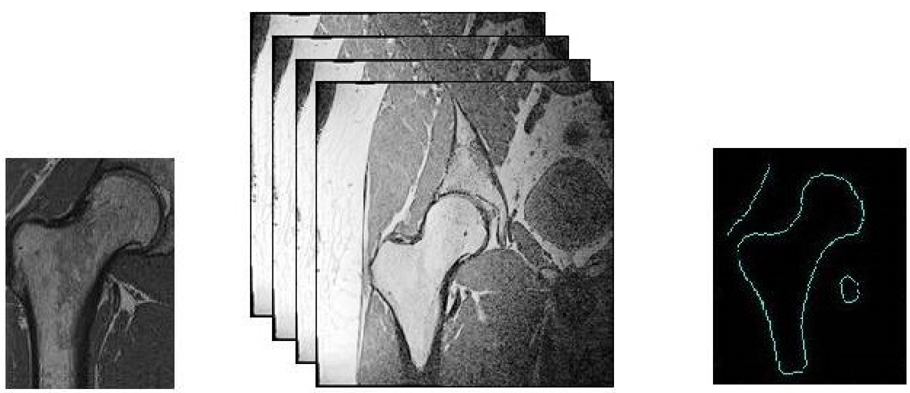


Figure 3: Bottom a test image to represent test image by the train image parts

5. EXPERIMENTAL RESULTS

The database consists of 20 MR images of size 256 x 256 of hip joint structure with their ground truth segmentation. The size of test image is 155 x 123. The canny edge detector is used for extraction of boundaries of test and train images. The threshold and sigma are 0.545 and 4 for the canny edge detector. The simulated annealing initial temperature parameter is 100. The affine transformation parameter for global detection is $0.863 \leq S_x \leq 0.982$ and $0.79 \leq S_y \leq 0.97$ as a scaling parameter in x and y direction. The rotation parameter is from -10 to 10 and translation parameter is $0 \leq t_x \leq 400$ and $0 \leq t_y \leq 400$ in x and y direction.



(a) (b) (c)

Figure 4: (a) Test image (b) MR image database and (c) Transformed test image.

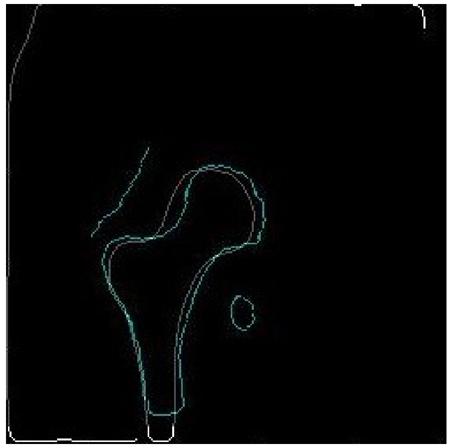
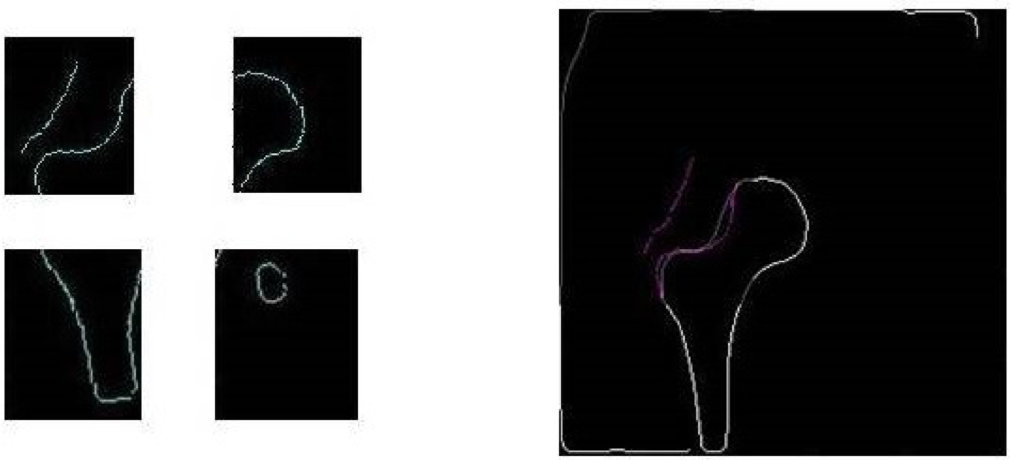
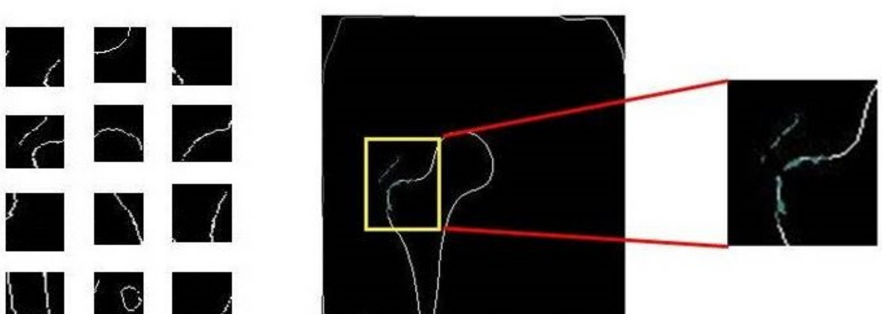


Figure 5: The global registration of test image over train image.



(a) (b)

Figure 6: (a) Decomposed test parts at level one and (b) Local part registration.



(a) (b)

Figure 7: (a) shows local parts at level two and (b) shows its registration with train images.

Figure 8: The segmentation of test image from ground truth data

6. CONCLUSIONS

We have proposed the novel method of image segmentation of hip joint structure in MR image. The method is to transfer ground truth segmentation from the train image database to the test image. The train image database consists of MR images of hip joint structure with their ground truth segmentation. The ground truth segmentation is done by medical experts. The method based on the top down approach to register test image globally and locally with the train images. The top down approach uses the hausdorff distance based shape registration algorithm. The objective of the top down approach is to find the best train image for each of the local test image parts. The bottom up approach uses the inverse transformation to match best train image parts with the original test image and the test image is represented by the mosaic of best train image parts. The ground truth segmentation from train image parts to their respective location of test image.

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