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Particle Swarm Optimization based K-mediods Clustering on Dental X-ray Images

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ABSTRACT- Images play a crucial role in various applications of engineering and sciences. Image is an artifact that depicts or records visual perception. With advancements in image capturing devices such as digital cameras, image scanners, most of the data is analyzed from digital images. Dentists use x-rays to find hidden dental structures, malignant or benign masses, bone loss and cavities.

KEYWORDS- Digital Images, X-rays, Dental Carie, Clustering, K-mediods

1. INTRODUCTION

1.1 What is Digital Imaging?

Digital Imaging has been referred to as the future of dentistry. Digital Imaging provides with

- Immediate Diagnosis with no down time for processing
- Reduced radiation exposure
- Patient records stored electronically

1.2 Why need Digital Dental X-rays?[1]

Digital Radiographs are original X-rays used by dental professionals to better detect, diagnose, treat and monitor oral conditions and diseases. Digital X-rays produce enhanced computer images of teeth, gums and other oral structures and conditions.

1.3 Why study Dental Carie?

The detection of dental caries, in early stage is very important. It is also known as dental decay or tooth decay. Primary diagnosis involves inspection of all visible tooth surfaces using basic tools including a good light source, explorer and dental mirror. Dental radiographs, or Dental X-rays, may show dental caries between the teeth, before it is visible through naked eye. Dental X-ray image analysis is major area of Digital Image processing [1].

1.4 What is Dental Carie?[14][7]

Dental caries and periodontal diseases are the most common dental diseases. If they are not treated in early stages, they may lead to progressive distraction of tooth and infection of the dental pulp.

1.5 How to obtain Dental Images?[2][3]

Dental images are generated simply by placing the patient between an X-ray source and a film sensitive to X-ray energy. Digital dental images are acquired through three methods: the direct method, indirect method and semi-indirect method. The direct method uses an electronic sensor placed in the mouth to record images. The indirect technique uses an X-ray film scanner to view traditional dental X-rays as digital images. The semi-indirect digital technique combines a sensor and scanner to convert dental X-rays into digital film.

1.6 Types of Digital Dental X-rays?[5]

- **Intraoral X-rays[13]**- Digital dental X-rays when taken inside the mouth, are called as Intraoral X-rays. These X-rays provide great detail of internal mouth problems, such as cavities, help to check status of developing teeth and monitor teeth and bone health.
  Various types of Intraoral X-rays are-
  1. **Bitewing X-rays**[6], show details of the upper and lower teeth in one area of the mouth. This gives details of the tooth from its top to the point where supporting bone exists. These x-rays give details of decay between the teeth and changes in bone density caused by gum disease as well as integrity of tooth fillings.
  2. **Periapical X-rays**, show details of whole tooth starting from its top to beyond the root tips to the supporting bone in one area of either the upper or lower jaw. These X-rays are used to detect root structure and surrounding bone loss around each tooth. Such X-rays help in treatment of advanced gum diseases and lesions

- **Extraoral X-rays[11]**- Digital dental X-rays which do not provide internal details of mouth or problems

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related to individual tooth. These X-rays are used to identify critical problems between teeth, such as detect impacted teeth, monitor jaw growth and development and problems related to joints or other facial bones. Various types of Extraoral X-rays are-

1. **Panoramic X-rays**- These X-rays are used for forensic and legal purposes to identify bodies which are not visible after fire, crashes or other fatalities by showing details of all the teeth in the upper and lower arch, in one image. These x-rays are used to plan treatment for dental implants, jaw problems, and to find bone tumors and cysts.
2. **Multi-slice computed tomography (MCT)**- These X-rays do not cover entire details of the mouth instead show a particular layer or slice of the mouth. These x-rays help to view structures that are not visible to naked eye.
3. **Cephalometric Projections**- These X-rays are generally preferred by Orthodontists to develop their treatment plan. These X-rays give details of entire head and help to examine teeth in relation to a patient's jaw and profile.
4. **Sialography**- These x-rays are used to identify salivary gland problems including blockages.
5. **Cone beam computerized tomography (CBCT)**- these X-rays are used to identify facial bone problems, such as tumors or fractures. These X-rays give three dimensional view and is helpful for evaluating bone for dental implant placement and difficult tooth extractions. This will help dentists to avoid possible complications during and after surgical procedures.

1.7 Structure of tooth

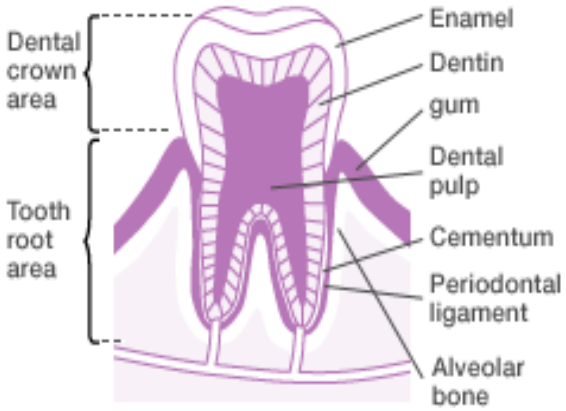

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Figure 1 : Tooth Structure[12]

A tooth consists of enamel, dentin, cementum and pulp tissue. The portion of a tooth exposed to the oral cavity is known as the dental crown[12], and the portion below the dental crown is known as the tooth root. The dental pulp cavity exists in the center of the tooth, through which the dental pulp, called the nerve, runs. In order to receive an impact on the tooth and to absorb and alleviate the force on the jaw, the surface of the tooth root area (cementum) and the alveolar bone are connected by a fibrous tissue called the periodontal ligament. The tooth is supported by the tissue consisting of the alveolar bone, gums and the periodontal ligament[12].

- Enamel: The hardest bodily tissue covering the surface of the dental crown. It is as hard as crystal.
- Dentin: The tissue that forms the tooth from the dental crown to the tooth root, situated inside the enamel and cementum. It is softer than the enamel. A small tube filled with tissue fluid, called the dentinal tubule, runs inside the dentin.
- Cementum: The tissue covering the surface of the tooth root. It connects the alveolar bone with the tooth by the periodontal ligament. Its hardness is similar to bone.
- Dental pulp: The tissue is called the nerve. Blood vessels and the lymph vessels, as well as nerve fibers, are located in the dental pulp, supplying nutrients to the dentin.
- Periodontal ligament: Tissue consisting mainly of the fibrous tissue that connects the tooth root and the alveolar bone. It prevents force applied to the tooth from being directly imposed on the alveolar bone while chewing food.
- Alveolar bone: The jaw bone supporting the tooth; the tooth is planted into this bone. When a large part of the alveolar bone is destroyed by periodontal disease or other causes, the tooth becomes loose.
- Gingiva: The soft tissue covering the alveolar bone. It is generally called "gum".
- Gingival sulcus: The small space between the tooth and the gums. Even people with healthy teeth usually have a depth of 1 to 2 mm in this space. When this space deepens due to inflammation, it is called the periodontal pocket or gingival pocket.

1.8 Problems associated with dental Images

Several images suffer from low resolution and lighting which would affect the quality of the desired dental feature recognition and labeling of individual tooth or major parts such as crown and root of the tooth. Each tooth or the desired object extracted from the image represents Region of Interest that contains important data used for later steps.

Classification of dental diseases is decided based on whether the lesion is within the enamel, dentin or whether it touches the pulp [1]. Based to the extent of attack dental caries may be classified as- Enamel, Dentinal and Pulpal

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caries. In enamel the caries have affected the outer enamel portion alone and the inner dentine and pulp regions are healthy. In Dentinal, the lateral spread at the dentino-enamel junction occurs with involvement of underlying dentin. In Pulpal, the micro-organisms have spread to root surface and affected roots.

1.9 Clinical Tools Available for detection of dental caries-[14]

The diagnosis of carious lesions[8] has been primarily a visual process, based principally on clinical inspection and review of radiographs. Tactile information obtained through use of the dental explorer or "probe" has also been used in the diagnostic process. The development of some alternative diagnostic methods, such as fiber optic trans illumination (FOTI) and direct digital imaging continue to rely on dentists' interpretation of visual cues, while other emerging methods, such as electrical conductance (EC) and computer analysis of digitized radiographic images, offer the first "objective" assessments, where visual and tactile cues are either supplemented or supplanted by quantitative measurements.

2 PARTICLE SWARM OPTIMIZATION[15][9][10]

Particle Swarm Optimization (PSO) is a population based stochastic optimization technique inspired by social behavior of bird flocking or fish schooling.

In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. PSO is guided by simple mathematical calculations, involving change in position and velocity of the particle. Each particle remembers its local best position and tends to move towards global best.

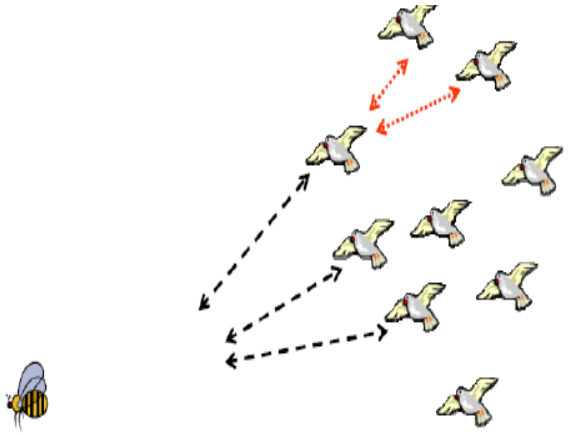


Figure-2 Bird flocking[15]

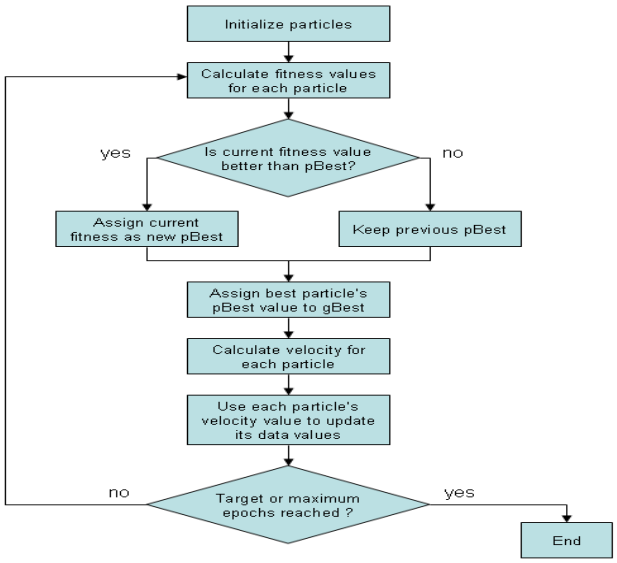


Figure 3. Flow diagram illustrating the particle swarm optimization algorithm.[12]

2.1 Pseudo Code For Particle Swarm Optimization based Evolutionary Technique

```
For each particle
{
   Initialize particle
}

Do until maximum iterations or minimum error criteria
{
   For each particle
   {
      Calculate Data fitness value
      If the fitness value is better than pBest
      {
         Set pBest = current fitness value
      }
      If pBest is better than gBest
      {
         Set gBest = pBest
      }
   }

   For each particle
   {
      Calculate particle Velocity
      Use gBest and Velocity to update particle Data
   }
```

3 PSO Based K-Mediods[16]

To reduce the complexities of K-means and to improve the detection rate, K-Medoids algorithm has been proposed . The K-Medoids algorithm basically divide the objects into k different clusters having same features. The K-Medoids algorithm is more robust to noise as well as to the outlier detection. A medoid is mainly the dataset which has minute dissimilarity. The algorithm is described as below.

Begin

(1) Obtain features of high priority than less priority from cluster size.
(2) Take medoids and use Euclidean distance to measure the dissimilarity between the clusters. After this sort out the clusters in an ascending order [37].
(3) Map each object with medoid that has close value and also find the optimal value from large number of objects
(4) Exchange the current medoid with the medoid that has minimum valu of dissimilarity.
(5) Again Exchange the current medoid with the medoid that has minimum value of dissimilarity. But if the value is same as the previous then algorithm will be stopped otherwise repeat step 4.

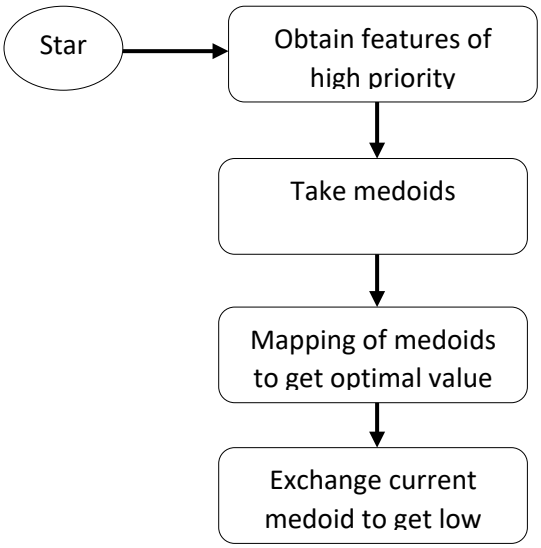


Figure- 4 PSO Based K-Medoids Algorithm

4 NEURAL NETWORK[15]

Neural network is based on the working of Human Brain or Neurons. It is used to extract patterns or detect trends that are complicated in nature and difficult for a human being to understand. This is used to solve Questions related to "what if" condition. Various advantages associated with Neural Network involves-

1. Adaptive learning: An ability to learn how to do tasks based on the data given for training or initial experience.
2. Self-Organization: An ANN can create its own organization or representation of the information it receives during learning time.
3. Real Time Operation: ANN computations may be carried out in parallel, and special hardware devices are being designed and manufactured which take advantage of this capability.
4. Fault Tolerance via Redundant Information Coding: Partial destruction of a network leads to the corresponding degradation of performance. However, some network capabilities may be retained even with major network damage

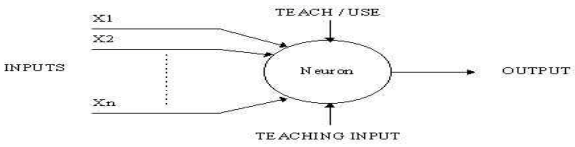
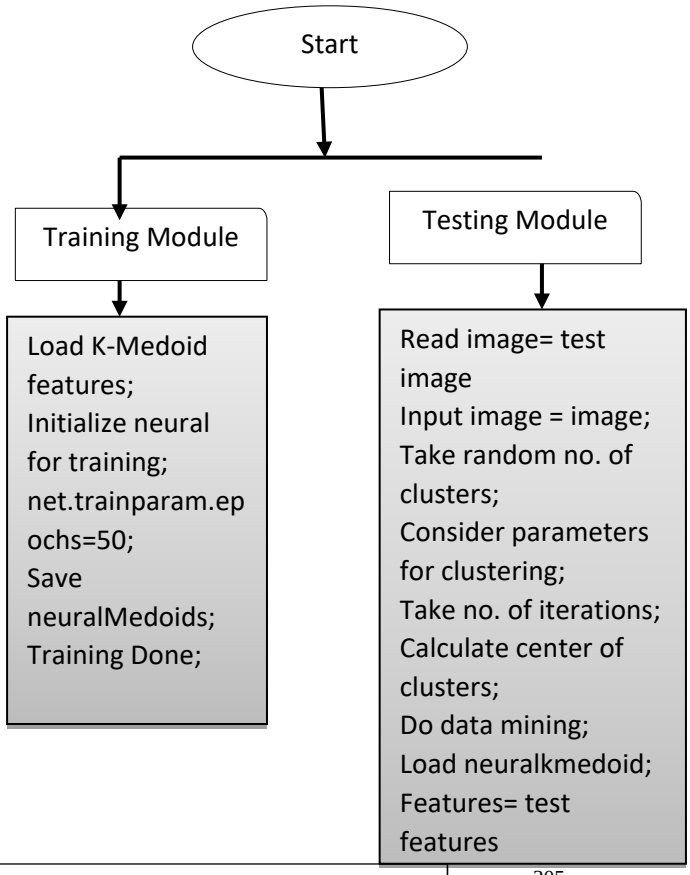


Figure-5 A Simple Neuron[15]

3 PROPOSED ALGORITHM[16]

- Training and testing using PSO based K-Medoids

The process of PSO K-Medoids clustering algorithm can be described as follows:
For training process;
Load K-Medoid features;
Initialize neural for training;
net.trainparam.epochs=50;
Save neuralMedoids;
Training Done;
For testing process;
Read image= test image
Input image = image;
Take random no. of clusters;
Consider parameters for clustering;
Take no. of iterations;
Calculate center of clusters;
Do data mining;
Load neuralkmedoid;
Features= test features;
Stop;



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4 Dental Image Classification Process-

1. Sample data set is prepared from dental X-ray images taken from various hospitals of Punjab region.
2. Features are extracted using PSO-K-mediods.
3. Principle Component analysis (PCA) is used to get distinguished or important features
4. Training of important features is done using Neural Network[15]
5. Particle Swarm Optimization based K-mediod clustering is applied on the trained data set to perform testing and classification of the cavity.

5 RESULTS

Figure- 6 GUI for Particle swarm optimization based K–Mediods on Dental X-ray Images

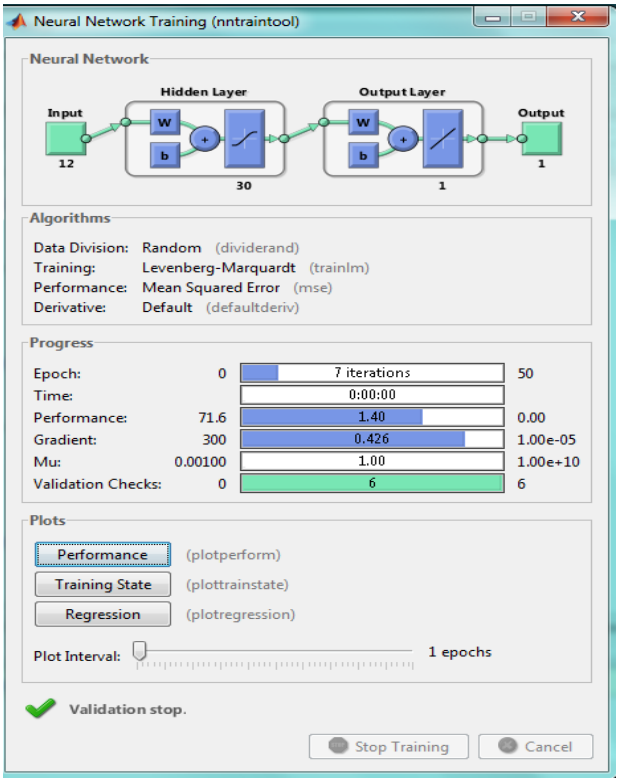

Figure -7 Training of feature vector for K-medoids Segmented Images

The above figure shows the training of K-medoids technique using neural network. Twelve feature that are used as Input and thirty hidden layers are used for training. The output of the training part is one as group or class.

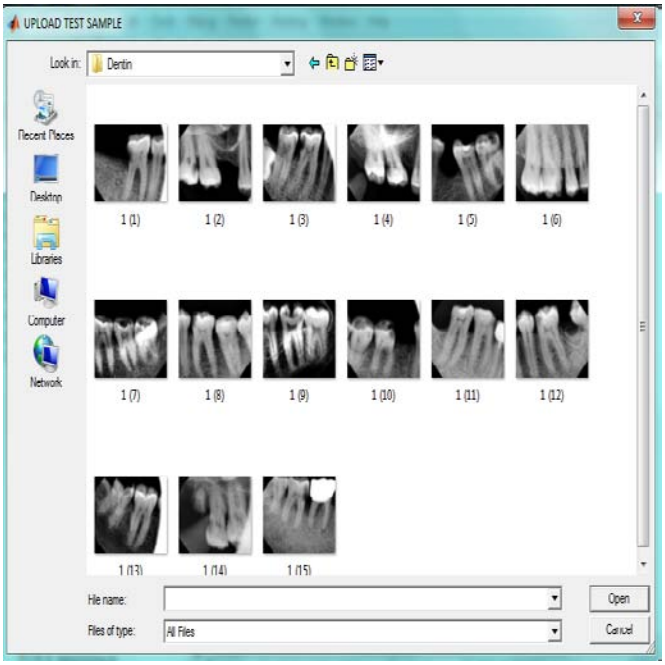

Figure-8 Load the test image while testing for k-medoids technique[16]

One image is being loaded and testing is being done to check the category of the test. As if there are nine categories, then the testing and the segmentation will be applied. The counting of the feature vector is done using PCA (Principle Component Analysis). 12 feature vectors are there using NN. If it is of K-medoid, so, the k-medoid segmentation will be applied.

Figure- 9 Segmented Image

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The segmented image is shown above of any of the image which is used for testing after applying segmentation. In Segmentation, the process of partitioning a digital image into multiple segments takes place. The objective of segmentation is to make simpler the illustration of an image in any meaningful image.

Table-1 Accuracy table

Types	PSO based K-mediods(%)
Dentin	98.8
Dentin-Dentin	98.5
Dentin-Dentin-Pulpal	98.9
Dentin-Pulpal	97.4
Pupal	94.5
Pulpal-Dentin	96.4
Pulpa-Pulpal	97.5
Pulpal-Pupal-Pulpal	99.5
Pulpal-Pulpal-Dentin	99.2

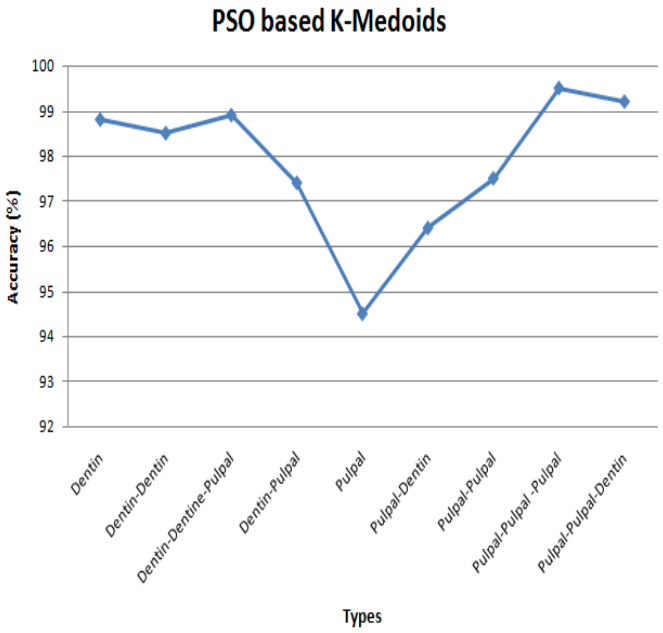

Figure-10 PSO Based K-Medoids Results

The above figure shows the segmentation results for various dental images using K-Medoid algorithm. Above figure shows that accuracy for segmentation using K-Medoids having Dentin = 98.8, Dentin-Dentin = 98.5, Dentin-Dentine-Pulpal = 98.9, Dentin-Pulpal = 97.4, Pulpal = 94.5, Pulpal-Dentin = 96.4, Pulpal-Pulpal = 97.5, Pulpal-Pulpal – Pulpal = 99.5 and Pulpal-Pulpal-Dentin = 99.2. As k-Medoids works on medoid that can be used, to centrally located object in a cluster. Thus, the partitioning method is performed based on the principle of minimizing the sum of the dissimilarities between each object and its corresponding reference point.

Algorithms	Time (sec)
PSO based K-Medoids	35

6 CONCLUSION AND FUTURE SCOPE

Dental segmentation is an important step in human identification and Content Based Image Retrieval (CBIR) systems. Also, Identifying the structure and arrangement of the teeth is one of the dentists' requirements for performing various procedures such as diagnosing abnormalities, dental implant and orthodontic planning.

This work proposes a methodology that incorporates PSO based clustering method with improved K-mediods for dental image segmentation. The use of the conventional PSO algorithm for medical image analysis is widespread because of its advantages, such as always being able to produce a complete division of the image. However, its drawbacks include over-segmentation and sensitivity to false edges. In the recent future various parameters can be chosen to measure the performance of the proposed technique like accuracy rate, time complexity etc

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