

## **CHAPTER 7**

### **Conclusion**

The summary of the proposed knee OA detection study and knee OA stages classification study using medical X-ray imagery, the main findings, the research contributions and direction for possible future study are presented in this chapter. The chapter organised as follow: the summary of the proposed knee OA and Knee OA stage classification presented in this thesis discussed in Section 7.1. While Section 7.2 presents the main findings and research contributions of the research work. Finally, Section 7.3 illustrates some guideline for the future research study.

#### **3.1 Summary**

In this thesis, there are three different approaches (texture-based, graph-based, and CNN) were proposed to classify knee OA and Knee OA stages with the respect to the ROIs of knee X-ray imagery applying. For the evaluation of these three approaches, the first approach applied four sub-images, when three sub-images datasets were applied for the second and the third approach. In each case an ROI identification was applied in the knee region of the X-ray image. With the respect to the original medical X-ray image presented in DICOM format, it produce a large size, thus, the segmented ROI produced the benefit of small size and unique for study to each approach. For each approach was finished in a different field: (i) texture-based, (ii) graph-based and (iii) convolutional neural network based (CNN-based).

The first approach in this thesis was founded by the texture based approach. In this approach the first step was considered as the ROI segmentation. With the respect to the ROI segmented process was illustrated, there are four ROIs were

identified from each knee X-ray image. Once, the ROIs were obtained is then applied. In the context of the work presented in this research, there were ten texture descriptors were considered. When the feature vector was completed, the feature selection (the process of feature space reduction) was then applied in order to build a feature space that suitable to classifier generation process. In the feature selection process, there are five well-known methods were used in the study, while in classification process, nine learning classifier learning algorithms were introduced. The evaluations: (i) in knee-OA detection, the best recorded classification accuracy was obtained from the femur bone region with neural network algorithm with CFS feature selection method; and (ii) in knee OA stage classification, the best result was obtained by the Tibia bone region with the logistic regression learning together with CFS feature selection.

The second approach was founded by the application of graph based to medical knee X-ray imagery. More specifically, the ROIs were identified. Once each ROI was segmented, the individual ROI was decomposed using quadtree. However, the quadtree representation does not depend on itself to incorporation with reference to learning method. In this case, the subgraph mining was applied to identify frequently occurring subgraph which can be used as feature in term of feature vector representation. The identified frequent subgraphs were view as defining a feature space which could be used to represent the image dataset. A given image dataset could thus be recast into this format so that each image is represented by a feature vector whose elements were some subset of the global set of identified frequent subgraph making up a feature space. The feature vector can be used directly to the learning classifier for the classification. The reported evaluation indicated that both knee OA detection and knee OA stages classification. The best accuracy results were obtained when applying low support threshold value for identifying occurring subgraph.

The third approach was founded by the concept of deep learning approach to medical image classification by using of convolutional neural network in transfer learning of AlexNet pre-trained model. More specifically, the ROI were segmented into three ROIs, where each ROI need to be resize to  $227 \times 227$  that the learning need to be trained for AlexNet. In the application of CNN model, the feature extraction process was removed which instead by learning feature by the layer of AlexNet model. When the model learned each ROI image feature, the classification

will be classify by the last layer of AlexNet model. The reported evaluation illustrated that for knee OA detection, the best classification accuracy was obtained by all the ROIs were segmented, while in knee OA stages classification best result was obtained from data set 3 (Otsu application to knee joint space) with neural network.

### **3.2 The Main Findings and Research Contributions**

In this section, the main findings of the thesis and some contributions are presented. The research presented in this thesis was provided directly with an answer to the research question presented in Chapter 1, namely:

*Can the knee OA and the stage knee OA can be predicted by applying classification technique and deep learning model to human joint X-ray imagery?*

This research question had a number of research issues that need to be resolution before an answer to the central research question could be derived. With respect to this thesis work, the main findings are presented with associated to research question and issues. This section is arranged by considering each of the research issues itemised in Chapter 1 in turn and then returning to the research question.

#### **1. What is the most appropriate ROI for classification study in case of knee OA detection study and knee OA stages detection study?**

There were two groups of ROI segmentation in this thesis. For the first ROI group was divided into four ROIs mentioned in Chapter 3 which was used in texture-based approach. For the second ROI group (SET B) is consisted of three ROIs mentioned in Chapter 3 which was used in graph-based approach and deep learning approach. The first was used in Chapter 4 and comprised three main process for the study (For knee OA detection the femur region performed well, while in knee OA stages the Tibia region produced the most accuracy for classification result). For the second ROI group was applied in Chapter 5 graph-based approach and Chapter 6 deep learning

approach. In graph based approach presented in Chapter 5, ROI was used with quadtree decomposition. In deep learning model study, ROI was used with CNN of transfer learning of AlexNet pretrained model. With the respect to the reported evaluation of best performance of both knee OA and knee OA stages detection in both graph-based and deep learning were performed by the Dataset 3 3 sub-image (the ROI segmented of knee joint space applied with Ostu method to make a clear joint space).

2. **What is the most appropriate feature extraction method in case of texture based approach for both knee OA and knee OA stages detection study?**

In this finding is presented only in texture based approach which was demonstrated in Chapter 4. Obtained ROI was presented the texture by texture descriptors. Ten texture descriptors were suggested to the work presented in this work in order to generate feature vector which was later used in classification. Amounts of ten texture descriptor the Local Binary Pattern (LBP) and its' family technique was the most effective of the study. As the study reported from the evaluation in chapter 4, LBP was the best texture descriptor technique for both knee OA and Knee OA stages classification applications.

3. **What is the most appropriate feature selection techniques in case of texture based approach for knee OA detection study?**

With the respect to Chapter 4 of texture based approach, after the texture descriptors were applied, the outcome of the descriptor was the feature space which contained of a number of features. In this case, feature selection were applied to reduce feature space dimensionality to make feature vectors that suitable to use directly with learning methods. The five well-known feature selections were applied in Chapter 4. As the reported of the evaluation illustrated that Correlation-based Feature Selection (CFS) was the best technique in context of knee OA study. Thus, CFS was applied in knee OA stages classification study and Chapter 5 about the graph-based approach and not further detail more of other feature selection techniques due to the CFS performance was the highest compare to others.

4. **What is most appropriate classification techniques for predicting knee OA and knee OA stages?**

The nine classifier generation methods were apply in texture based approach was presented in Chapter 4. When the feature selection process was completed, the reduction feature vector and the classifier generation was then commenced. With the study reported that in case of knee OA detection study, the best three of classifier generation mechanisms were Bayesian Network, then followed by Logistic Regression and the last was presented by Naïve Bayes classifier. For knee OA stages classification, the best three method illustrated that the best method was presented by Logistic Regression, followed up by Bayesian Network then finished by Naïve Bayes classifier.

5. **In case of graph base approach, what is most appropriate support threshold value for predicting knee OA and knee OA stages study?**

There were five support threshold values presented in Chapter 5 of graph-based approach. With the application of quadtree decomposition and subgraph mining to bulid the feature vector with CFS feature selection. The support threshold is the primary factor that is important for frequent subgraph mining. As the reported of the evaluation, the low support threshold values was driven the best performance to both study of knee OA and knee OA stages detection.

6. **Is the performance of deep learning model powerful for predicting knee OA and knee OA stages study?**

In the deep learning model to medial image analysis has not been widely used. Thus, the efficiency of deep learning for knee OA and knee OA stages classification was also considered as the main finding in this thesis work. With the application of CNN deep learning using AlexNet pre-trained model, the feature extraction process was removed. Therefore, the hidden layer of CNN worked as the learning feature and classification. The result of the study presented in Chapter 6 reported that, for knee OA detection, CNN was powerful to deal with the task, while in the knee OA stages detection, the predicted accuracy was accepted with the application of CNN.

Back to the initial research question, the knee OA and the stage of knee OA can be predicted by applying classification technique and deep learning method to human joint X-ray imagery can be founded on the process that encompasses: (i) in case of texture-based study, for knee OA detection, the Femur bone region (ROI) performed a well prediction, while in knee OA stages classification the Tibia bone region (ROI) can produced a well prediction. In case of graph-based approach and deep learning approach the Otsu knee join space segmented image was suggested, (ii) in case of texture-based approach, the LBP feature descriptor was preferred for knee OA and knee OA stage classification, (iii) CFS was the most appropriate feature selection that produced the best classification results of knee OA and knee OA stages, (iv) in the context of learning classification techniques Bayesian Network was the most appropriate technique for OA detection technique, while Logistic Regression performed the best result for OA stage classification, (v) in graph-based approach, the low support threshold produced the best classification performance, (vi) deep learning approach performed a good classification performance on OA detection, however it was not well with OA stage classification (highest AUC of 0.6296). The experiment results indicated that a good prediction of knee OA and knee OA stages could be obtained at very little cost.

The primary contribution of the research work illustrated in this thesis where pictured in Section 1.4 of Chapter 1, for convenient all the contributions are again discussed below. Note that in each case of the related chapter where the contribution was establish is given in parenthesis.

1. A knee sub-image (ROI) representation founded on the concept of “texture” analysis. More specifically applying of Local Binary Patterns (LBPs), as before a feature vector format was build.
2. A knee sub-image representation founded on the concept of “graph based” by applying the quadtree hierarchical decomposition together with frequent subgraph mining for reducing the feature dimensionality. The identifier frequent subgraph were set to a feature vector format, one vector per ROI, suited for input into a learning classifier.

3. An approach of deep learning approach was done without manually feature extraction process.
4. An analysis of a sequence of the proposed sub-image (ROI) so as to identify the most appropriate ROIs in term of knee OA classification from X-ray images.
5. An analysis of a sequence of the proposed ROI feature extraction algorithm so as to select the most appropriate in term of knee OA classification from X-ray images.
6. An analysis of a sequence of feature selection algorithm so as to select the most appropriate in term of knee OA classification from X-ray images.
7. An analysis of a sequence of classifier generation algorithm so as to select the most appropriate in term of knee OA classification from X-ray images.

### **3.2 Future Works**

The research pictured in this thesis has a number of the guideline that can be considered for the future works. In the concluding of this thesis, and this chapter, theses future works guideline are summarised as below:

#### **1. Perceptual Browsing Component (PBC) and Similarity Retrieval Component (SRC) texture Descriptor for feature extraction.**

In term of the texture based approach presented in Chapter 4, the texture feature of each ROI was extracted by 10 texture descriptors (LBP, LBP-HF, RLBP, CLBP, and etc.,). However, the texture feature can be extracted further more on the structuredness of feature by applying Perceptual Browsing Component (PBC) and Similarity Retrieval Component (SRC). A proposed study of addressing Perceptual

Browsing Component (PBC) and Similarity Retrieval Component (SRC) for image texture analysis presented in work [84].

## **2. The Weighted frequent subgraph mining**

In the work of graph-based application illustrated in Chapter 5, frequent subgraph mining was used to identify frequently occurring subgraph which were used to build the feature vectors. However, the subgraph mining process works by allocating a count of 1 to present the region in knee image and 0 is outside the knee region; it take no account of the number of time it appears. The algorithm to address this is to adopt what is called as weighted subgrap mining. The work [88] presented the application of weighted frequent subgraph mining.

In conclusion the work illustrated in this thesis has demonstrated that it is possible to predict knee OA and knee OA stages within a given knee medical x-ray imagery at a much reduce cost that that which would take with medical doctor to analyse.

## **3. Deep Recurrent Neural Networks for knee Osteoarthritis detection and classification.**

With the application of CNN deep learning presented in Chapter 6, CNN performed well for Knee OA detection, and acceptable accuracy for knee OA stages classification. Thus, Deep Recurrent Neural Networks (RNN) which one of the famous deep learning model may be good direction for the study in this thesis. A mechanism of RNN have been presented in [85, 86, 87] for image analysis.

In conclusion the work illustrated in this thesis has demonstrated that it is possible to classify knee OA and knee OA stages within a given knee medical x-ray imagery at a much reduce cost that that which would take with medical doctor to analyse.