**Chapter 7**

**Conclusion**

In summary of the proposed knee OA detection study and knee OA stages classification study using medical X-ray imagery and processes, the main findings, the research contributions and direction for possible future study are pictured in this chapter. The chapter organized as follow: the summary of the proposed knee OA and Knee OA stage classification presented in this thesis illustrated in Section 7.1. Section 7.2 presents the main findings and research contributions of the research work. Lastly, Section 9.3 illustrates some guideline for the future research study.

**7.1 Summary**

In this thesis, there are three different approach (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 classification. For the evaluation of these three approaches, the first approach approach apply to 4 subimage datasets and 3 subimage datasets were applied for the second and the third approach, were applied. In each case an ROI segmentation 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 produce 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) convolutional neural network for deep learning based, and (iii) graph based. For prediction model training purposed of knee OA detection and knee OA stages classification were considered.

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 segmented form each knee X-ray image. Once, the ROIs were segmented, the feature extraction of applying 10 texture descriptors to each ROI was consider. The application of texture descriptor can produce a feature space, then feature selection for used to reduce feature space in term of number and dimensionality in order to build the feature vector that is suitable to apply with classifier generation for classification process. In the feature selection process, there are five well-known were used in the study, while in classification process, nine learning classifier were introduced. The reported evaluation illustrated that for knee OA detection study recorded that the best classification accuracy were obtained the femur bone region with neural network algorithm. In the contrary, the knee OA stages classification best result were obtained by the Tibia bone region with the logistic regression learning.

The second approach was founded by the application of graph based to medical knee X-ray imagery. More specifically, the ROIs were segmented the same to ROIs in the second approach. Once each ROI was segmented, the individual ROI were presented 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 are 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 study best accuracy result 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 227x227 that the learning need to be trained for AlexNet. In the application of CNN model, the manually feature extraction was remove 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 study recorded that the best classification accuracy were obtained by all the ROIs were segmented, while in knee OA stages classification best result were obtained by the Algorithm 3 (Otsu;s application to knee joint space segmented image) with neural network.

**7.2 The main Finding and Research Contribution**

In this section, the main finding 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 issue that need to be resolution before an answer to the central research question could be derived. With respect to tis thesis work, the main findings are presented with associated to research question and issue. 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?**

Three are two groups of ROI segmentation in this thesis. For the first ROI group is divided into four ROIs mention in chapter 3 which is used in texture based approach. For the second ROI group is consist of three ROIs mentioned in chapter 3 which is used is graph based approach and deep learning model. The first was used in chapter 4 and comprise three main process for the study (For knee OA detection the femur region perform well, while in knee OA stages the Tibia region produce the most accuracy for classification result). For the second ROI group was applied in Chapter 5 and Chapter 6 of deep learning model and graph based approach respectively. In deep learning model study, ROI were used with CNN of transfer learning of AlexNet pre-trained model. For graph based approach was presented in Chapter 6, ROI was applied with quadtree decomposition. With the respect to the reported evaluation of best performance of both knee OA and knee OA stages detection in both deep learning and graph based was performed by the Algorithm 3 subimage (the ROI segemented of knee joint space applied with Ostu’s method to make a clear joint space).

1. **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 illustrated in Chapter 4. With the respect to ROI segmented was presented in Chapter 3, each ROI was extract the texture by texture descriptor. With the application of 10 texture descriptors to each ROI in order extract feature that could be considered further for feature selection to build feature vector and forward to classification process for predict both knee OA and knee OA stages. Amounts of 10 texture descriptor the Local Binary Pattern (LBP) ant its’ family technique was the most effective of the study. As the study reported from the evaluation in chapter 4, LBP was the best technique of 10 technique for both knee OA and Knee OA stages classification.

1. **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 is the feature space. In this case, feature selection were applied to reduce feature space dimensionality to make feature vectors that suitable to use directly with learning classifier. There are five well-known feature selections were applied in Chapter 4. As the reported of the evaluation illustrated that Correlation-based Feature Selection (CFS) is the best technique in case of knee OA study. Thus, CFS was applied in knee OA stages classification study and Chapter 6 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.

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

Three are nine classifier generation were apply in texture based approach was presented in Chapter 4. After finishing the feature selection process, the outcome was feature vector which can be applied with classifier generation method for knee OA and OA stages classification. With the study reported that in case of knee OA detection study, the best three of classifier generation illustrated that the best performance by 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.

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

There are five support threshold values are presented in Chapter 5 of graph based approach for knee OA and knee OA stages classification. 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 quadtree decomposition. 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.

1. **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 considered as the main finding in this thesis work. With the application of CNN deep learning applied with AlexNet pre-trained model, the manually feature extraction was removed. Therefore, the hidden layer of CNN worked as the learning feature and classification. As the result of the study presented in Chapter 5 presented that, for knee OA detection, CNN are 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 knee OA can be predicted by applying classification technique and deep learning model 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) can perform a well prediction, while in knee OA stages classification the Tibia bone region (ROI) can produce a well prediction. In case of deep learning model and graph based approach the application of Otsu’s to knee join space segmented image is prefer, (ii) In case of Texture based approach, the LBP feature descriptor is preferred for prediction both of knee OA and knee OA stage, (iii) CFS is the most appropriate feature selection that can drive to the best result prediction of knee OA and knee OA stages, (iv) With the classification technique of knee OA detection study in case of texture based approach, Bayesian Network is most appropriate technique for prediction. For Knee OA stages classification in term of texture based, Logistic Regression is the best appropriate for prediction, (v) With the application of graph based approach, the low support threshold support can drive the best result of prediction, (vi) In term of deep learning application, knee OA detection was well predicted with CNN deep learning model, while in knee OA stages classification the accuracy of the predicted result are acceptable (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 model for classification without manually feature extraction.
4. An analysis of a sequence of the proposed sub-image (ROI) so as to identify the most appropriate ROI in term of knee OA detection from X-ray images.
5. An analysis of a sequence of the proposed ROI image representation algorithm so as to select the most appropriate in term of knee OA detection 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 detection 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 detection from X-ray images.

**7.3 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 summaries illustrated 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 [80].

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

With the application of CNN deep learning presented in Chapter 5, 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 [81] [82] [83] for image analysis.

1. **The Weighted frequent subgraph mining**

In the work of grap based application illustrated in Chapter 6, 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 [84] 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.