Title

Written by

Group 17gr7402

1. Semester
School of Medicine and Health
Biomedical Engineering and Informatics
Fredrik Bajers Vej 7
9220 Aalborg

Title:
title title

Theme:
Biomedical Signals and Information

Project Period:
Fall semester 2017

Project Group:
17gr7402

Participants:
Birgithe Kleemann Rasmussen
Ignas Kupcikevičius
Linette Helena Poulsen
Mads Kristensen

Supervisor(s)
Shellie Boudreau
Lasse Riis Østergaard

Page Numbers:
Appendix:
Date of Completion: 20/12/2017

Abstract

Preface

Bla bæa

Contents

Chapter 1

Methodology

This chapter is created to give an overview of the worksheet's structure and how the literature is found described. The purpose of this worksheet is to list the fundamental understanding needed and the findings from which the scientific article is formed.

1.1 Structure of the worksheet

The worksheet is structured after background knowledge that contains anatomy of the knee, pain and pain maps, knee pain regions, machine learning and deep learning. The knowledge of the anatomic of the knee, pain and pain maps support the understanding of patellofemoral pain and the given pain maps. Machine learning and deep learning is necessary for development of the model to process the data.
After the chapter Background is the aim of the project presented, which directs to the chapter Materials, where the data and program for developing the deep learning model is described. Next is the pre-processing elaborated followed by the data processing and results.

1.2 Literature

For collecting literature is there used unstructured and structured searching. The unstructured is primary used in the beginning of the project, where the approach to the literature was wide and nonspecific. This was used to get a lot of keywords to further structured searching. The structured searching is used to develop the worksheet and the scientific article. Literature is primarily new and peer reviewed articles or textbooks.

Chapter 2

Background

This chapter contains the background knowledge to optimise the understanding of patellofemoral pain and deep learning. The chapter will contain the following sections; anatomy of the knee, pain and pain mapping, knee pain regions. Futhermore, are machine learning and deep learning specified.

2.1 Anatomy of the Knee

The knee is the largest synovial joint in the body and consists of a hinge and a gliding joint. The hinge joint is placed between the lateral and medial femoral condyles and the lateral and medial tibial condyles. Between the patella and femur is the gliding joint formed. The structure of the knee is illustrated in figure 2.1.[1]

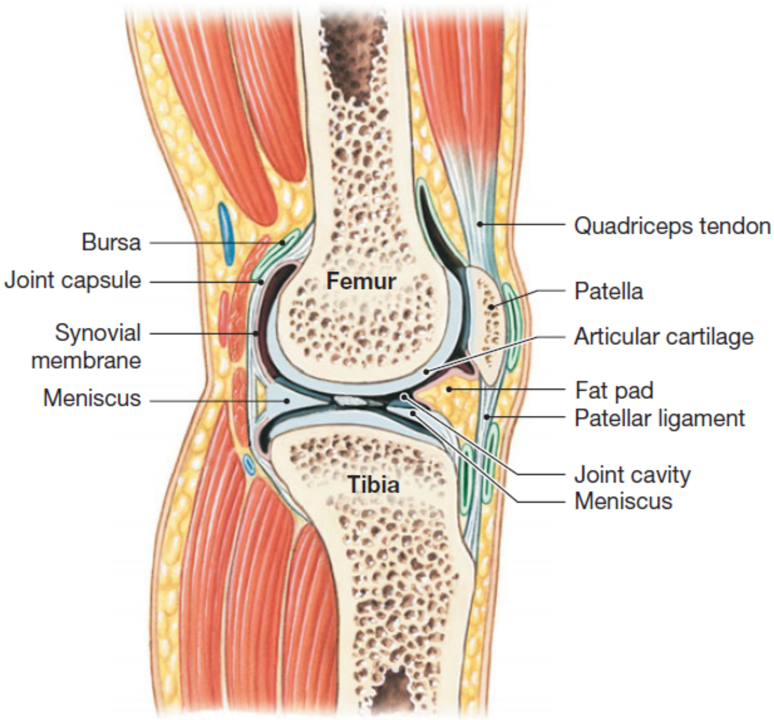

Figure 2.1: *The figure illustrates the anatomy of the knee with focus on the ligaments. Edited from [1].*

It is shown at figure 2.1 that the patella is a sesamoid bone, which at birth consists of cartilaginous and ossifies when the child's extremities gets stronger, which typically proceeds between age two or three and the beginning of the puberty. The patella is surrounded by the tendon of the quadriceps femoris. Quadriceps femoris is the muscles which controls the extending of the knee. The quadriceps tendon is combined to the surface anterior and superior of patella. Tibia is combined to the anterior and inferior surface of the patella by the patellar ligament. The bones, tibia and femur, are covered by articular cartilage, which purpose is to protect the bones from friction. The articular cartilage on the two bones are separated from one another by synovial membranes that contains synovial fluid, that further reduce the friction. The primary functions of the synovial fluid is to lubricate, distribution of nutrient and absorption of shock.[1]

Between the articular cartilage is the fat pads and menisci placed. The fat pads' function is to protect the cartilage and fill out space as result of the joint cavity changes. The menisci stabilize the knee and acts like pads, that conform shape when femur moves. In addition to fat pads and menisci acts bursa as friction minimization between patella and tissues.[1]
There are three separate articulations in the knee joint, which is one between the patella and the patellar surface of the femur and two between the femoral and tibial condyles. Additionally, the knee consist of seven major ligaments that stabilize the knee joint, which shown as figure 2.2.[1]

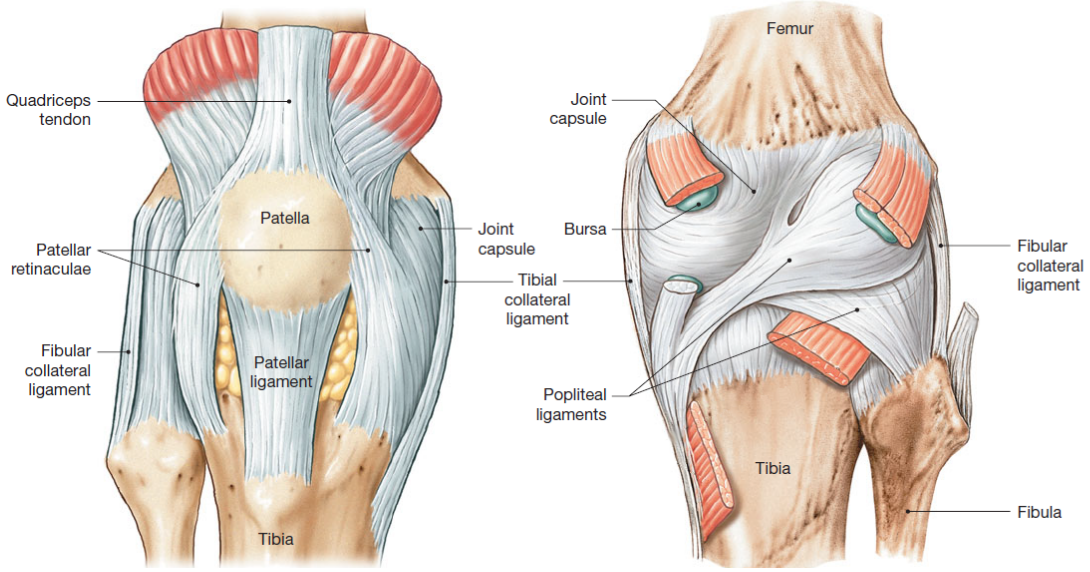

Figure 2.2: *The figure illustrates the anatomy of the knee with focus on the ligaments. Edited from [1].*

To support the anterior surface of the knee are the ligaments patellar retinaculae and patellar ligament. When the knee is fully extended the tibial and fibular collateral ligament are responsible for stabilizing the joint. Between femur and the two lower bones in the leg, tibia and fibula, is there two popliteal ligaments, which stabilize the posterior surface of the joint. In addition to the visible ligaments in figure 2.2 are there anterior cruciate ligament (ACI) and posterior cruciate ligament (PCI) in the joint capsule. The two ligaments cross over each other and are connected to the tibial and femoral condyles. They reduce the movement, anterior and posterior.[1]

As previously mentioned the gliding joint is formed between the patella and femur, so that during knee movement patella is gliding up and down at the femoral condyle. A condition associated with incorrect movement of the patella, is patellofemoral pain syndrome (PFPS), that occurs when the patella moves outside of its ordinary track, which for instance can be movement in lateral direction.[1]

2.2 Pain

Pain is experienced and perceived subjectively and there is a lack of methods to measure pain accurately [2, 3]. The International Association for the Study of Pain (IASP) has defined pain as being “an unpleasant sensory and emotional experience associated with actual or potential tissue damage” [2].

Physiologically pain can be divided into three categories: Acute pain (less than three months), persistent or chronic pain and cancer pain. Furthermore, pain can be either nociceptive or neuropathic. Nociceptive pain is associated with tissue damage. Neuropathic is associated with damage to the nervous system.[4]

2.2.1 Pain mapping

Pain mapping is a technique, that Harold Palmer introduced in 1949 [5], which is used to transfer a patient’s perceived pain into an objective graph or map by drawing the pain area. Pain drawings can be made by the patients who draw their pain areas on a display on which a body outline is shown, or it can be made by observers who observe the patients and then draw from the signs the patients are showing. An example of a body outline is shown at figure **??**. Pain maps can consist of only the drawings, but sometimes a questionnaire is added to get a more detailed overview of the pain.[6]

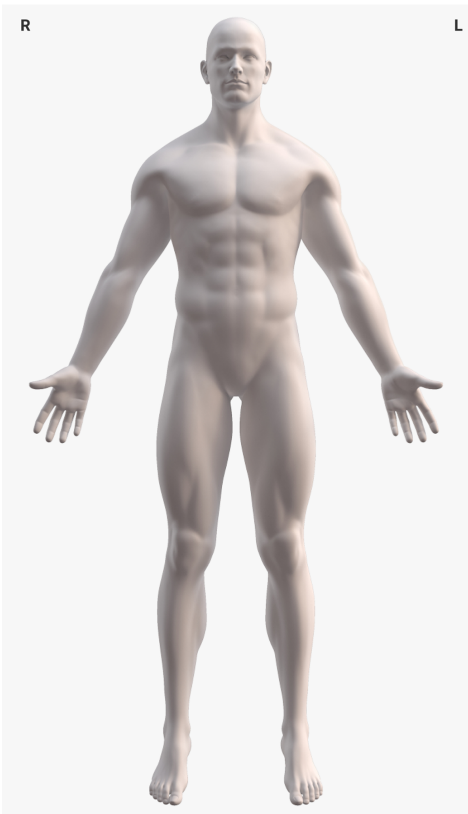

Figure 2.3: *The figure illustrates a body outline for pain drawing.*

Pain mapping are commonly used in clinical practice [6], and can be useful for patients when they try to communicate their pain. Pain maps may also be helpful in diagnosing patients and follow-ups during or after treatment to get an indicator of the patient’s response to the treatment.[7] According to Schott there are some issues with the graphical representations of pain, some of which are problems with drawing a three-dimensional feeling of pain on a two-dimensional surface, and distinguishing between internal and external perceived pain on a map.[6]

Knee pain regions

Patients with PFP often describe the knee pain as a diffuse pain, and when looking at pain drawing samples from multiple patients it is also evident that there is a high variability in how pain patterns are distributed across different areas of the knee. To distinguish between different pain areas, the knee can be divided into various regions as seen in Figure 2.4, where atlases of the left and right anterior knee are illustrated. The atlases has been provided by Shellie Boudreau.

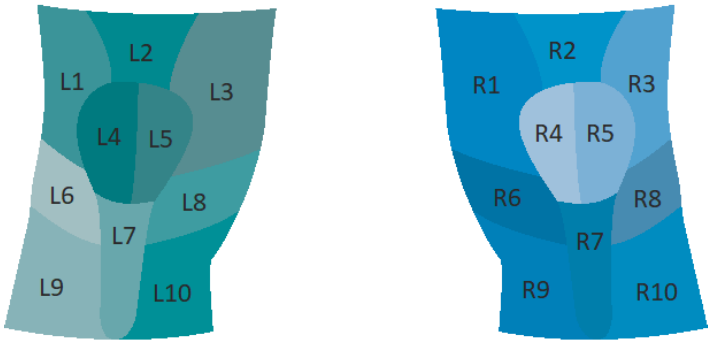

Figure 2.4: *The figure illustrates atlases of the left and right knee.*

2.3 Machine learning

Machine learning (ML) describes the use of algorithms to make a system able to identify different data types, like images or text, for transcription of speech into text, matching news items, posts or selection of relevant results of search [8]. ML is a method there uses inductive inference, which identifies rules in a dataset from given input and output [9]. If the computer learns this feature, it can be used to make intelligent decisions and predict specific outcomes. [9] It is a field that has seen a lot of progress over the past decades, partially because developers recognize the ease in training a system only using examples of the desired in- and output behavior. This is simply easier than trying to manually write a piece of code that anticipate different scenarios from different types input. [10]

2.3.1 Deep Learning

Information about deep learning (what is deep learning): Deep learning is a branch of machine learning. The main difference between the use of ML and deep learning, is that first one is not suitable for handle raw data form. Instead a machine learning system often needs a feature extractor, that will generate a feature vector from the data that can be used as an input for the ML system. [8] Deep learning is based on different techniques that makes it able to handle that data in its raw form, mainly because of it's structure. [8, 11]. Because of this the system will automatically detect the necessary representations needed for classification and detection [8]. The neural network consists of different layers, that can be divided into a input-layer and an output-layer, with one or more hidden layers in between [8, 11]. The key aspect of these layers is that the features are not defined by programmers, but they are found and learned from raw data using a general – purpose learning procedure. [8] An example of the structure can be seen in Figure 2.5.

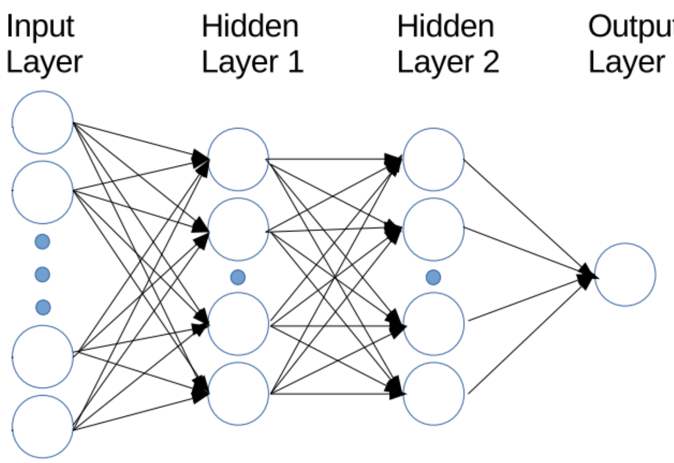

Figure 2.5: *BLABLABLA[12].*

The different layers consist of a series of processors/Neurons/Nodes, where each node is connected to one or several other nodes from a different layer. In the input-layer the nodes are fed with the data that the system is given. The second layer will then receive the output from the previous layer, and this processes continues through the layers until the output-layer is reached. [11] An example of how the hidden layers affect the data e.g. an image can be explained as follows: Firstly, the system detects minor changes like edges. Secondly, the edges are compared and put together to make up different kind of shapes. In the third hidden layer, it will be further combined to make up an object that can be identified. [8]

2.3.2 Supervised Learning

Supervised learning is the most common way of training in machine learning [8]. When using this method the system is trained with labeled data, where the generated output can be compared with an expected output, and thereby see how accurate the system is. By adjusting weights inside the neural network it is possible to fit the model better to the training data, and thereby increase its accuracy and reduce error. [8] Supervised learning is mostly associated with classification, regression, and ranking problems [13].

2.3.3 Unsupervised Learning

Differently from supervised learning in this scenario the input is received with unlabeled data and the predictions are made for all unseen points [13]. An example of an unsupervised learning algorithm is clustering, where the unlabeled dataset goes through a classification, and split into different classes. [14]

2.3.4 Semi-supervised Learning

In this scenario, the learner is receiving both labeled, unlabeled data and then it makes prediction for all unseen points. It is used mainly when the labeled data is hardly collected and unlabeled data is easily reachable [13].

2.3.5 Convolutional Neural Networks

CNN perform highly in several tasks, including digit recognition, image classification and face recognition. The key aspect of CNNs is to automatically learn a complex model that is able to extract visual features from the pixel-level content. Operations like filtering, local contrast normalization, nonlinear activation and local pooling are being used [12]. CNNs are a feed – forward models that maps input data with a set of suitable outputs. Accuracy and performance rely on large training datasets and training procedure based on back-propagation with optimization algorithm such as gradient descent [12].

2.3.6 Backpropagation

Back – propagation is a popular learning algorithm in convolutional neural network. It is valuable because of the simplicity, computationally efficient and because it usually works [15]. Basic idea behind it is to minimize the overall output error as much as possible during the learning stage. This algorithm process is divided in two main stages: forward and backward. In the first process (forward), the BP architecture is described as the inputs and weights multiplication of each neuron (separate input) summed with biases [16].

In the backward process, weights will be updated to minimize the error between target and output layer. This process will be applied until optimal weights with minimum error is reached [16].

Chapter 3

Aim of the project

In this project the focus is patellofemoral pain and how accurate the duration of the pain can be predicted by using different methods. PFP occurs as diffuse knee pain there makes it hard for patients to explain and point out the precise pain area. Furthermore it is hard for healthcare personnel to interpret and give a treatment for the conditions. Since the pain is perceived as diffuse and seems very different from person to person, is it assumed that the data is non-linear. To compensate for the differences in pain maps it is chosen to superimpose an atlas of the knee to the pain maps to help define the different pain regions with labels. This makes it possible to use deep neural network to predict the duration of the subjects pain. In addition to this model a simple correlation model is used to compare the accuracy of the models. Based on this the following hypothesis is formulated.

Hypothesis: It is hypothesized that deep neural network performs more accurate than a simple correlation, when predicting the duration of patellofemoral pain from active pain regions.

Chapter 4

Materials

Materials contains a describtion of the given data of PFP subjects and which program there is used to form the deep learning model to predict the duration of the PFP.

4.1 Data

Data used in this study were collected before this study. This data consists of pain map drawings which were drawn by subjects with PFP through the use of an application Navigate Pain in a clinical setting. The data contained information regarding the subjects in terms of i.a. age, gender, height and weight. For each individual subject information related to the PFPS was also collected, regarding the duration of PFP and which knee was the most prominent for pain. The number of samples available during this study was collected from ??? subjects with PFP. An example of a pain drawing can be seen in figure 4.1.

Figure 4.1: *Pain drawings of the lower extremities. The red markings indicate the area of pain perceived by the individual subject. In this case the PFP is bilateral (on both knees).*

4.1.1 Navigate Pain

Navigate Pain is an application there is used to visualise the location, shape and spatial distribution of pain from patient to healthcare personnel. The application permits subjects to draw their pain into a body outline with different colors and line thickness. Navigate Pain is developed by Algance Solutions within Aalborg University in Denmark.[17] Figure 4.2 illustrate the process using the application.

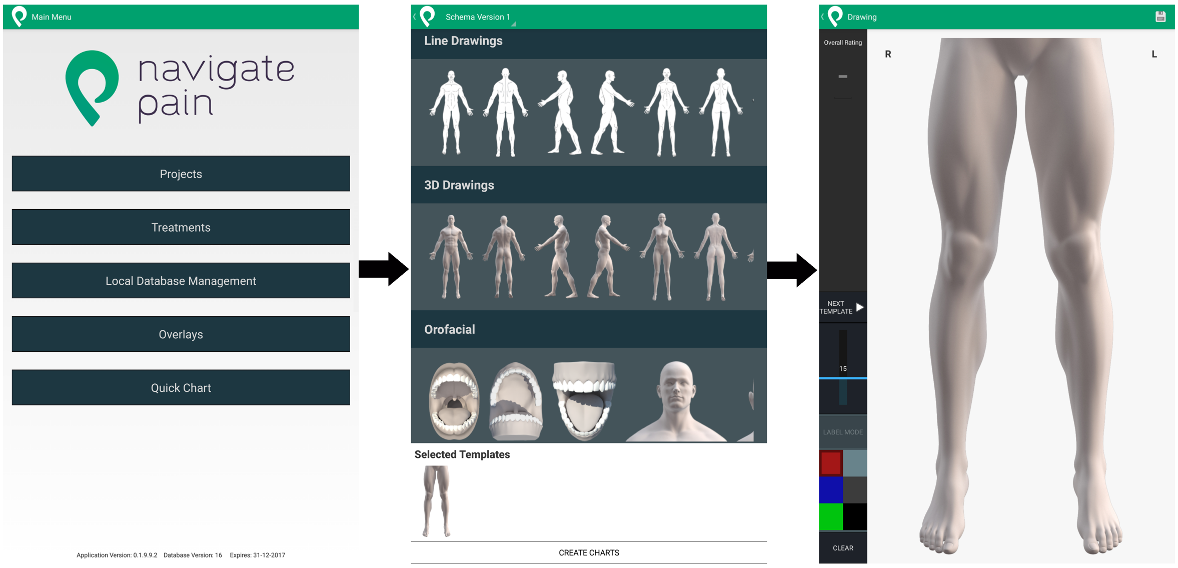

Figure 4.2: *The figure illustrates the process for making a pain map with Navigate Pain. There is three screenshots of the application.*

The first screen in figure 4.2 is the main screen. By clicking on "Project" a folder with subjects is created. From each subject is information like name, age, height saved. Before the subject can draw their pain areas, the body outline has to be chosen, which the second screenshot illustrates. The body outlines is divided into five categories: Line Drawings, 3D Drawings, Orofacial, Special Zooms and Knee Pain. In the bottom the seleceted templates is shown. When clicking on "CREATE CHARTS" the third screenshot is shown. Here is it possible to draw the pain areas with different colors and line thickness, which can be seen in the left side of the screen. Afterwards can the pain map be saved.

4.2 Program

Chapter 5

Data Processing and results

5.1 Data

Bibliography

[1] Frederic H. et. al. Martini. *Anatomy & Physology*. 2012.

[2] IASP. IASP Taxonomy, 2012.

[3] Jarred Younger and Sean Mackey. Pain outcomes: A brief review of instruments and techniques. 2009.

[4] Emma Briggs. Understanding the experience and physiology of pain. 2010.

[5] Marie Grunnesjö. The course of pain drawings during a 10-week treatment period in patients with acute and sub-acute low back pain. 2006. doi: 10.1186/1471-2474-7-65.

[6] Geoffrey D. Schott. The cartography of pain: The evolving contribution of pain maps. 2010. doi: 10.1016/j.ejpain.2009.12.005.

[7] Shellie A. Boudreau and Susanne et.al Badsberg. Digital pain drawings: Assessing Touch-Screen Technology and 3D Body Schemas. 2016. doi: 10.1097/AJP.0000000000000230.

[8] Yann LeCun, Yoshua Bengio, and Geoffrey Hinton. Deep Learning. *Nature Insight Review*, pages 436–444, 2015. doi: 10.1038/nature14539. URL `https://www.nature.com/nature/journal/v521/n7553/pdf/nature14539.pdf`.

[9] Mads Nielsen. *Den digitale revolution – fortællinger fra datalogiens verden*. Datalogisk Institut, 2010. ISBN 978-87-981270-5-5.

[10] M. I. Jordan and T. M. Mitchell. Machine learning: Trends, perspectives, and prospects. *Science*, 349(6245):255–260, 2015. ISSN 0036-8075. doi: 10.1126/science.aaa8415. URL `http://www.sciencemag.org/cgi/doi/10.1126/science.aaa8415`.

[11] Jürgen Schmidhuber. Deep Learning in Neural Networks: An Overview. *Neural Networks*, 61:85–117, 2015. ISSN 18792782. doi: 10.1016/j.neunet.2014.09.003. URL `http://www.sciencedirect.com/science/article/pii/S0893608014002135`.

[12] Jacopo Acquarelli, Twan van Laarhoven, Jan Gerretzen, Thanh N. Tran, Lutgarde M.C. Buydens, and Elena Marchiori. Convolutional neural networks for vibrational spectroscopic data analysis. *Analytica Chimica Acta*, 954:22–31, 2017. ISSN 18734324. doi: 10.1016/j.aca.2016.12.010. URL `http://linkinghub.elsevier.com/retrieve/pii/S0003267016314842`.

[13] Mohri Mehryar, Rostamizadeh Afshin, and Talwalka Ameet. *Foundations of Machine Learning*. 2012. ISBN 9780262018258. URL `https://ebookcentral.proquest.com/lib/aalborguniv-ebooks/reader.action?docID=3339482{&}ppg=17{#}`.

[14] Ian Goodfellow, Yoshua Bengio, and Aaron Courville. *Deep Learning*. MIT Press, 2016. URL http://www.deeplearningbook.org.

[15] Yoshua Bengio. *Neural Networks: Tricks of the Trade: Second Edition*. 2012. ISBN 978-3-642-35289-8. doi: 10.1007/978-3-642-35289-8_26. URL http://dx.doi.org/10.1007/978-3-642-35289-8{_}26.

[16] Alaa Ali Hameed, Bekir Karlik, and Mohammad Shukri Salman. Back-propagation algorithm with variable adaptive momentum. *Knowledge-Based Systems*, 114:79–87, 2016. ISSN 09507051. doi: 10.1016/j.knosys.2016.10.001. URL http://www.sciencedirect.com/science/article/pii/S0950705116303811?via{%}3Dihub.

[17] Aglance Solutions. Visual insight for clinical reasoning – Navigate Pain, 2015. URL http://www.navigatepain.com/.

Appendix A

Appendix