INFLUENCE OF PIXEL DIMENSIONS IN PERFORMANCE OF CONVOLUTIONAL NEURAL NETWORK FOR CELL IMAGE CLASSIFICATION

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In many of the image based classification applications we use images of different pixel dimensions to train the neural networks for classification. Using large amounts of pixel data will result in consumption of more main memory since convolutional Neural Networks (CNN) would need to store more parameters to train the network; further to pass these gradients through backpropagation larger computational graphs needs to be stored, this results in higher memory and runtime. This study aims in observing and understanding the influence of image pixel density on computational parameters such as runtime and number of parameters to be trained and accuracy of the neural network. Further, from this study it is observed that a high density coloured image does not necessarily result in better metrics such as accuracy of neural network but using grey scaled images with not very high density is more optimal in terms of better accuracy, reduced time and memory requirements.

KEYWORDS: Image dimensionality/density, accuracy, memory, overfitting, convolutional neural network.

INTRODUCTION: Articular cartilage defects are caused due to acute cell damage or aging which results to damaged or missing cartilage. There are various tissue development to improve the condition, one such technique is to use adult stem cells (Catherine Baugé et al.) in cartilage tissue regeneration, stem cells which can partially differentiate into various types of cells and proliferate indefinitely to produce more of the same stem cell and are used to convert into chondrocyte cells which are present in cartilage, this helps in restoration of the damaged cartilage tissues. In this process, it is important to identify if the cells are differentiated, there are different techniques such as Immunohistological analysis, RNA isolation and reverse transcription and Fluorescence activated cell sorting analysis etc. are available in stem cells differentiation characterization. (Computational Intelligence in Engineering et al.), but many of these expensive and often time consuming further these methods uses the cellular material for analysis which could be more valuable in cell therapy. As a convenient alternative machine learning approaches could be used to classify images, there are many well established techniques for classification in the field of machine learning such as logistic regression, clustering methods, support vector machines but these methods deal with limited number of samples and computing units(Xin, M., Wang, Y et al.). But in recent times there deep learning methods especially convolutional neural networks are preferred for image classification because of better feature extraction and better weights readjustments which greatly results in improving the accuracy of the network (Xin, M., Wang, et al.). In this analysis a convolutional neural network with three convolutional layers (G. C. Lee, K. Haung, C. Sun and Y. Liao et al.) is implemented to classify cell images. The image data provided will result in accuracy > 0.9 for the CNN with even with reduced image density. More quantified results are presented in the later sections.

METHODS: The provided dataset consists of 147 and 64 images of stem cells and chondrocytes respectively, each image has the dimension of width = 2560 pixels and height = 1920 with 3 channels (RGB), the analysis is divided into two major categories. First using Grey scaled images and then coloured images (RGB), for each of the case, images are resized into smaller dimensions starting from 10x10 pixels then increasing progressively till 80x80 pixels (this is the hardware limit on my system with 8 GB RAM). Then, the data is split for training and validation (0.75:0.25). Further to data argumentation of horizontal and vertical flip is performed because this process creates diversity in the training data thus also reduce overfitting (Shorten, C., Khoshgoftaar et al.). In particular, additional training images are obtained by horizontal and vertical flip, so data is increased two folds (1 original+ 2 additional). Since the objective here is to compare data pixels effects of grey scaled and colour data influence, all other parameters are kept exactly the same for both the analysis. This data is used to train the convolutional neural network (CNN) for 50 epochs. The network has two convolution layers with 16, 192 filters with 5x5 kernel size and activated by rectified linear activation function; this is passed into a fully connected dense layer with 200 neurons which is connected to a output layer for binary classification.

RESULTS: By performing the analysis in the conditions set in 'methods' section the following results are observed. Although there are many parameters that can be obtained after training the network, here we consider the three important parameters that will show us the contrasting distinctions between RGB and Grey scaled images for varying pixel dimensions.
By looking at the values of "Number of parameters" in Table 1 or semi-log subplot on number of parameters in Figure 1, it is observed that there is an exponential increase in number of parameters required by increasing the pixels linearly. Further, as expected the run time is increasing for both cases nonlinearly with increasing pixel dimensions and the accuracy in general is better for grey scaled images than on RGB irrespective of number of pixels dimensions used for training the CNN. And highest accuracy of 92% is reached for CNN using gray scale with 50 pixel images.

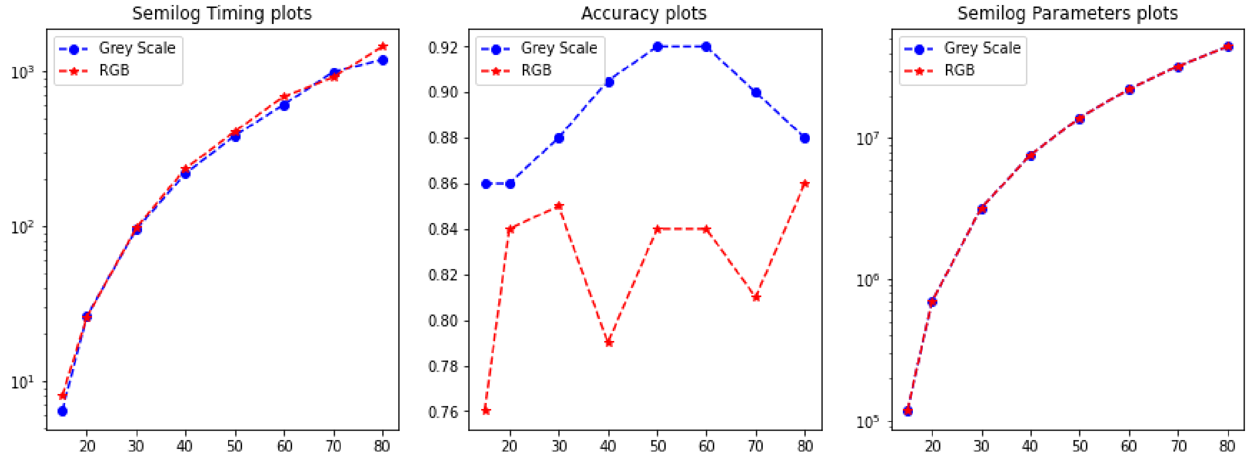

Figure 1: Plots for Performance parameters (X-axis: pixel dimensions, Y-axis: timing, accuracy, number of parameters).

Pixel Dimensions	GREY SCALE IMAGE			RGB IMAGE		
	Time	Number of Parameters	Accuracy	Time	Number of Parameters	Accuracy
15	6.4	116209	0.86	8.05	117009	0.76
20	26.10	692209	0.86	25.76	693009	0.84
30	94.95	3188209	0.88	97.08	3189009	0.85
40	218.14	7606209	0.90	235.03	7605009	0.79
50	382.68	13940209	**0.92**	407.42	13941009	0.84
60	608.87	22196209	**0.92**	686.44	22197009	0.84
70	988.28	32372209	0.90	913.15	32373009	0.81
80	1191.11	44468209	0.88	1441.61	44469009	0.86

Table 1: The result data with parameters related to performance.

DISCUSSION: From the results is it possible to discuss about this study in two different aspects. The first aspect is relation between pixel dimensions on timing and accuracy. As it can be observed from Figure 1 the timing and number of parameters increases as the number of pixels increases. The reason not because of the number of weights of the filters, but it is in fact due the wrights and biases after the flattened layer that is used as inputs to the feed forward neural network. Although there will be same number of weights in CNN layers (because same CNN kernels/filters are used for all the cases) if we use image with larger pixels irrespective of grey scale or RGB, the size of input to feed forward layer will drastically increase as large dimensional image will have a huge dimensions of the activation map. This will result in large sizes of weight matrices. Due to this we get the memory constrains because all this weights has to be built in a graph to train the network model using reverse mode algorithmic differentiation. So this will consume memory space and thus in training them requires more time. The second aspect to consider is effect of pixel dimensions on accuracy. Although it is tempting to assume that more pixel data results in higher testing set accuracy, as seen from Figure 1 it is not true, the reason is overfitting on training set data, since we are using a high dimensional pixels image means more features, but same training data so model will over fit, to deal with it we could use more images for training or use other methods such as regularization or dropouts. So in this case it is seen that best accuracy is obtained when training the network with images with 50 to 60 pixel dimensions in grey scale. Also it is observed here that grey scaled images perform (in terms of accuracy) than RGB, I suspect the reason could be because more weights are used in first layer which causes variability (i.e 25 weights in Grey scale, 75 weights in RGB) this is similar to underfit but only in first layer so using grey scale will reduce the features in first layer by one third so it takes care of under fit, but further analysis maybe required in this aspect.

CONCLUSION:

From this study, it is shown that the accuracy of CNN for grey scales images is higher than RGB. Further, for medium density pixel images (approx. 50 pixels per image) the accuracy is highest (reaching 92%), this can be considered as is optimal in terms of both accuracy and computational cost since medium density pixel images consume less memory and faster to train the network. In fact, in this study using images with density not only takes more time, memory to train but also gives worst accuracy.

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