TRANSFER LEARNING IN MEDICAL IMAGE ANALYSIS: A SURVEY

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Abstract

Medical sector is advancing tremendously with Artificial Intelligence. Machine Learning and Deep Learning algorithms are becoming popular in solving many problems which handle medical images. Deep learning models require vast amount of data. Transfer Learning technique opens a new path for working with limited data sets especially in the areas where public data are not available in surplus quantity. This paper carries out a survey to identify studies on employing transfer learning in medical images.

Keywords: Transfer Learning, Deep Learning, Machine Learning, Artificial Intelligence, Medical Imaging

I INTRODUCTION

By building smart machines which simulates human intelligence, Artificial Intelligence is becoming more popular. Machine Learning (ML) and Deep Learning (DL), which are the subsets of Artificial Intelligence, find its applications in wide range of areas such as Image Recognition, product recommendation, spam filtering, speech recognition, self-driving cars, video surveillance, medical image analysis, etc. ML and DL algorithms are developed to perform specific tasks.

Deep learning models require enormous amount of data. But certain real-world data such as patient data, financial data, etc. would not be available to the public in large quantity. Day by day, machine learning and deep learning models are budding in medical imaging. As we don't have adequate data in medical imaging, Transfer Learning (TL) is widely used instead of training a network from the scratch. Transfer Learning means moving (transferring) of knowledge (which is learnt in the past) from one situation to another situation. i.e., TL helps to reuse a pretrained model to solve a new problem. For example, a model built to classify a dog image can be used to classify a cat, or the one used to classify shirt image to classify a skirt or the one which classifies a mango to classify a lemon and so on.

To train a neural network from the scratch, enormous amount of data is required. Transfer Learning helps to deal with the lack of data by enabling the reuse of a previously learned model on a new problem [1]. TL is a powerful technique for developing Deep Learning models. Time and effort spend in training different Machine Learning models can be saved by implementing TL which speeds up the training process and also improves the performance [2].

TL helps to classify or segment 2Dor3D medical images captured using various devices. It is used in a wide range of problems such as, diabetic retinopathy detection, lung image segmentation, various cancer classification, Alzheimer's detection brain MRI segmentation, etc. This work reviews the studies carried out in the past 3 years on medical image analysis using transfer learning.

The paper is structured as follows. An overview of transfer learning is discussed in Section II which covers the categories, approaches and applications of TL. SectionIII is composed of a study on TL problems and models developed in the last 3years followed by a discussion in Section IV. Section V concludes the paper.

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II OVERVIEW OF TRANSFER LEARNING

A. What is Transfer Learning?

We can define Transfer Learning as a machine learning method where a model developed for a task is reused as the starting point for a model on a second task [3]. TL finds various application in areas such as Computer Vision, Natural Language Processing, Audio Speech Recognition, etc.

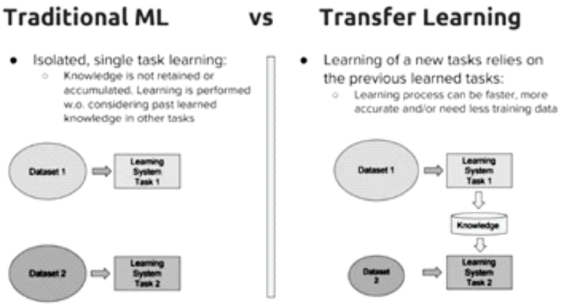

Fig.1. Traditional Learning vs Transfer Learning

Fig.1[5] shows how learning takes place in a traditional ML model and how knowledge is transferred in a model using TL.

Major advantages of Transfer Learning are that it saves training time, shows better performance of neural networks and it does not require large amount of data [4]. Deep Learning models solve complex tasks and such algorithms require huge amount of data for better learning and to produce more accurate results. TL helps us to utilize knowledge from previously learned tasks and apply to newer, related ones [5].

B. Categories of Transfer Learning

Three categories of Transfer Learning Methods are:

1) Inductive Transfer Learning: Here, both the source domain and target domains are same but the tasks' performances are different [5].

2) Unsupervised Transfer Learning: Same as Inductive TL. The difference is that, labeled data is unavailable in source and target domains [5].

3) Transductive Transfer Learning: Here, source and target tasks are same but the domains are different. And source domain contains a lot of labeled data whereas target domain has none [5].

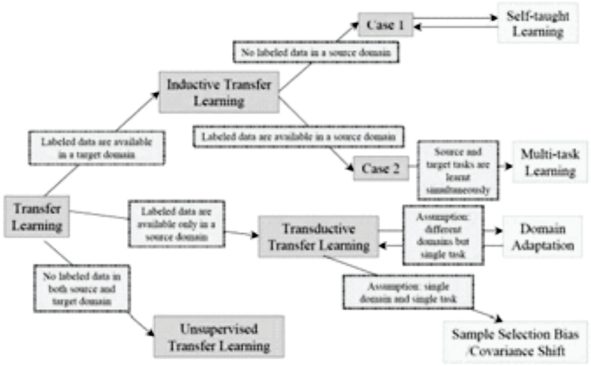

Fig.2. Transfer Learning Strategies

Fig.2[5] depicts the different strategies of Transfer Learning.

Deep Transfer Learning follows inductive learning approach. Inductive learning algorithms infer mapping from asset of training examples [5].

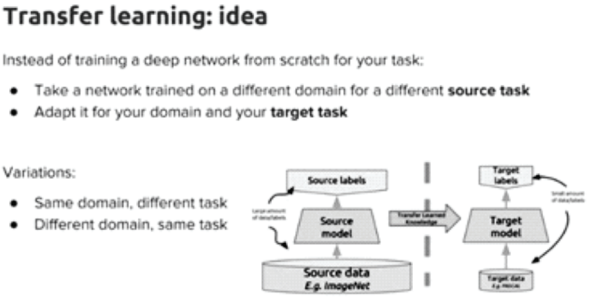

Fig.3. DeepTransfer Learning

Fig.3. [5]gives an idea about deep transfer learning.

C. Transfer Learning Approaches

The different Transfer Learning approaches are:

1) Training a model to reuse it: If we don't have enough data to train a deep neural network for solving a problem, then train the network with are lasted task which has abundant data and use this network as an initial point to solve our problem [4].

2) Using a Pretrained model: In this approach, we use a pre-trained model to solve our problem. It is the most commonly used model in deep learning [4].

3) Feature Extraction: Deep learning can be used to find out the important features of our problem, which is also known as representation learning. These learned representations can be used as initial layers for solving other problems which could result in better performance of the model [4].

D. Applications of Transfer Learning

Some of the applications of transfer learning include:

1) Technologies:

a) Image Recognition: TL can be applied if the training dataset is ether an image or a video. A TL model used for identifying one object can be used to identify another object [6].

b) Natural Language Processing (NLP): Models which recognize linguistic structures can be used to develop other models which could predict next word in a sentence [6].

c) Speech Recognition: A model which performs Russian speech recognition can be used to develop a model for English speech recognition [6].

2) Industries:

a) Autonomous Driving: A model meant for detecting one object/vehicle on the road can be used to detect other objects / vehicles on the road [6].

b) Gaming: Models developed for playing strategies on games can be re-used on other games with similar strategy [6].

c) Healthcare: Models can be re-used in Gesture recognition, medical imaging etc [6].

d) Spam Filtering: A model which categorize emails can be used for spam filtering [6].

III SURVEY ON TRANSFER LEARNING MODELS

A survey has been carried out on Transfer Learning techniques applied on different problems which uses medical images. The most relevant papers published between 2019 and 2021 are discussed here.

In 2019, [7] classified 3 major types of brain tumor with minimum preprocessing steps. They used deep transfer learning to learn features from brain MRI images. The paper also discussed about the misclassification aspects.

[8] Performed 4binary classification tasks in Alzheimer's Disease (AD) classification using volumetric CNN with MRI images. The results were visualized using feature maps which gave explainability to the classification tasks. They made use of Convolutional Autoencoders and transfer learning for their study.

[9] developed 6 different deep TL models with CNN architecture models for the early detection of diabetic retinopathy disease. Model classified indentifies images into5 classes. Among the 6 models developed AlexNet offered greater accuracy.

[10] Explored 2TL models-Nas Netand Mobile Net for the abnormality classification in breast mammogram. The performance of the models was then compared with Resnet

50 and Inception V3 in which Mobile Net and Resnet 50 gave greater accuracy.

[11] proposed a model for diagnosing brain diseases. They developed three deep CNNs for feature extraction from brain MRI images and Support Vector Machine (SVM) to classify the MRI images into healthy, stroke and Alzheimer's Disease.

In 2020, [12] used 5 pretrained models which are trained on Image Net dataset, for learning features from different X-ray images and prediction was made by a classifier. An ensemble model was developed by combining the predictions from the 5 pretrained models. Final prediction was made by implementing majority voting technique.

[13] proposed a deep CNN with TL for the diagnosis of Diabetic Foot Ulcer (DFU). They experimented TL with both different and same domains of targeted tasks and proved that source of TL from same domain of targeted dataset performs better.

To detect and classify breast cancer using histological images, [14] developed 5 CNN models with TL. Among those models, they achieved good results withVGG19 model and Dense Net model provided greater accuracy.

In 2021, [15] applied modifications in the five layers of CNN and TL architecture for the automatic detection of brain tumor and they gained 100% result in accuracy, specificity and sensitivity. To ensure the effectiveness of the proposed model, they used two different datasets for evaluation.

A deep CNN and TL model has been proposed by [16] for skin cancer classification. Preprocessing, normalization and data augmentation were applied on the data for getting more accurate results. HAM 1000 data set is used for model evaluation and the model classified skin lesions into malignant and benign classes with a greater accuracy.

[17] developed a model for automatic detection ofCovid-19 from CT scans. They employed an ensemble of 5 models and TL with deep CNN and the model have shown a great performance compared to the performances of individual networks.

IV DISCUSSION

A study, on the importance and use of Transfer Learning in medical image analysis, has been made in this paper. Some of the relevant papers of last 3 years is being discussed and listed here. The problems, data used in those problems, Transfer Learning techniques used to solve the problems and its performance measurements are shown in Table I.

Reference Paper	Year	Problem and TypeofDatausead	Methodology	Performance
[7]	2019	Brain tumorclassificationfrom MRIimages	DeepTL	Accuracy-98%
[8]	2019	Classification andVisualization	Volumetric CNNand TL	Accuracy-AD-86.60%pMCI-73.95%
[9]	2019	EarlydetectionofDiabeticRetinopathy	DeepTLmodels	Accuracy-97.9%
[10]	2019	Breast MammogramAbnormalitiesClassification fromDICOMimages	TL	Accuracy-MobileNet-74.3%Resnet50-78.4%
[11]	2019	Brain MRIClassification	TLandSVM	Accuracy-100%
[12]	2020	PneumoniaDetection from chestX-rayimages	Ensemble of 5ModelsandTL	Accuracy-96.4%Recall-99.62%
[13]	2020	Diagnosis ofDiabeticFootUlcer fromDFUDataset	Deep CNN andTL	F1-score-97.6%
[14]	2020	Breast CancerClassificationusing histologicalimages	Deep CNN andTL	Sensitivity - VGG19-93.05%
[15]	2021	Brain TumorDetection from MRIimages	CNNandTL	Accuracy, SpecificityandSensitivity-100%
[16]	2021	SkinCancer Classification fromskinlesionimages	Deep CNN andTL	Accuracy-91.93%
[17]	2021	Automatic detectionof Covid-19 fromCTscans	Ensemble of TLanddeep CNN	Accuracy-85%

Table I. Overview of Transfer Learning Techiniques applied Indifferentproblems

V CONCLUSION

A survey has been carried out on how transfer learning is helpful in the analysis of medical image data. The problem description, input data type, methodology used and performance measurement has been summarized.

From this study it is clear that Transfer Learning enable researchers in working with less data, getting better results andsavingtheirtime.Thissurveywouldbehelpfulfortheresearchersintheirfuture TLstudies.

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