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Proposing the deep dynamic Bayesian network as a future computer based medical system

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Abstract—The development of new learning models has been of great importance throughout recent years; with a focus on creating advances in the area of deep learning. Deep learning was first noted in 2006, and has since become a major area of research in a number of disciplines. This paper will delve into the area of deep learning to present its current limitations and provide a new idea for a fully integrated deep and dynamic probabilistic system. The new model will be applicable to a vast number of areas initially focusing on applications into medical image analysis with an overall goal of utilising this approach for prediction purposes in computer based medical systems.

Index Terms—probabilistic graphical model; deep learning; dynamic Bayesian network; medical systems

I. INTRODUCTION

The research area of signal processing has broadened its applications in recent years due to the increasing interest in machine learning [1]. Deep learning is a subset of machine learning which considers approaches of learning through multiple levels; this is done by allowing mathematical models composed of multiple processing layers to learn information about the data with multiple levels of abstraction [2]. Dynamic models capture the important information and relations amongst variables in a system. This paper wishes to present the proposed deep dynamic Bayesian network which takes a standard well accepted approach known as the Bayesian network and adds a dynamic aspect to capture data over multiple time points and depth through multiple layers of information thus presenting the deep dynamic Bayesian network and its relevance to future computer based medical systems.

The paper is organized as follows: Section II will provide an insight into deep learning and the relevant architectures. Particular emphasis will be placed in Section II-A which discusses deep Belief networks. In Section III the concept of modelling dynamic systems will be presented to emphasise the importance of incorporating these approaches through the use of dynamic Bayesian networks. Section IV describes the concept of a novel system which incorporates components from both deep Belief networks and dynamic Bayesian networks. The development of a novel network such as this will be beneficial in a number of applications, one of which, will be covered in Section V. The initial application of this research will be in the area of medical image analysis whereby the proposed model aims to assist clinicians in future analysis.

II. DEEP LEARNING

Deep learning is the newest subset of machine learning which has been of interest to researchers since 2006, when it was first introduced in [3]. This new area of research has become increasingly important in many disciplines; from statistics to computer science.

Before the area of deep learning, machine learning techniques explicitly used shallow architectures i.e. a system containing only one layer to represent the hidden aspect of a system. This hidden layer allows for the components of a system that are not directly observable to be accounted for in the analysis. These types of architectures are not always applicable to real-world dynamical systems as there may be a number of unobservable components that have an impact throughout the sequence of data. The main aim is to develop new learning techniques with the ability to extract important information and complex structures from various input sources. Deep learning architectures are built with multiple layers of non-linear processing stages which are used to represent the information contained within the system that is being modelled [2].

A. Deep Belief networks

Deep Belief networks are probabilistic generative models that are made up of multiple layers of stochastic variables. The hidden variables relate to some part of the system to be modelled that is directly unobservable. Literature relating to deep Belief networks indicates how the structure of the network is built; through a stack of restricted Boltzmann machines (RBMs). RBMs are a type of Markov random field that contains two stochastic layers; one consisting of only hidden units, and the other, observable units [1]. There a number of learning algorithms noted throughout the literature relating to the learning of the network and how inference is performed. An overview of the current area is provided in [1] whereby the requirement for future developments in the area of deep learning are discussed. Figure 1 provides a graphical representation of a deep Belief network involving a small number of variables.

III. DYNAMIC COMPONENT

There has been few attempts to date to incorporate a temporal or dynamic component into deep learning with regards

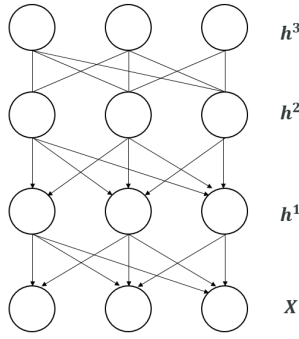


Fig. 1. A graphical representation of a Deep Belief Network with the observed vector X and three hidden layers. The top two layers represent a RBM which is an undirected graphical model.

to deep Belief networks. The development of a DBN-HMM (Deep Belief network hidden Markov model) has started to make significant contribution in the area however, there has been no developed model that has fully integrated the temporal component into a deep Belief network. The benefits of including a dynamic component are vast, with one important benefit being the ability to model a dynamic system that involves sequential time dependent data. The ability to construct these models by using the time dependent data will allow for better analysis with multiple levels of abstraction as current deep networks assume a static domain. The development of such models would meet part of the challenges currently experienced by clinical researchers who have access to complex data sets being generated over multiple time points with hidden layers of uncertainty.

A. Dynamic Bayesian network

Dynamic Bayesian networks (DBNs) will be investigated in such a way to discover how the inclusion of a dynamic component allows the network to model real-world systems. Bayesian networks (BNs) are a type of probabilistic graphical model that are used to capture relationships between a set of random variables where the probabilistic nature of model allows uncertainty in a system to be modelled appropriately. This aspect makes them an appropriate model choice for the analysis of multiple domain areas. DBNs are an extension of the traditional Bayesian network which incorporates a temporal dimension [4]. The inclusion of this is crucial in modelling real-world systems and thus the development of a new deep dynamic model would benefit statistical analysis of these systems. Figure 2 is presented to display the relations between variables across the different time points. The diagram shows how the variables are impacted from previous time points and thus this network is used to model different dynamically changing data.

IV. DISCUSSION OF DDBN

The aim for this research is to create a new mathematical framework that forms the basis of future computer based medical systems that represent a novel learning model incorporating

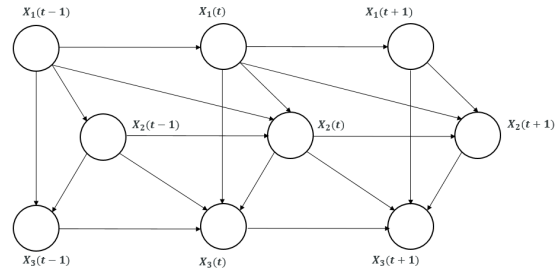


Fig. 2. An example of the structure of a dynamic Bayesian network with three variables X_1, X_2, X_3 across three time points.

the temporal component discussed in Section III into a network containing multiple hidden layers. This research will help in the development of a new model that is a fully integrated system that focuses on the hidden layers within and how they change throughout the dynamic process that is to be modelled; thus the system will be both deep and dynamic. The new network will be defined as a deep dynamic Bayesian network (DDBN). By incorporating a temporal component to the current deep belief network it is hoped that the network will also provide a more efficient and accurate approach than that which is currently used. Section V will discuss one application of this research.

V. APPLICATIONS

The possible application areas of this research are vast, however the initial focus will be on modelling medical time series data. The advances in medical imaging has opened up new possibilities for research; through analysis and interpretation of medical images. The applications of previous work to medical images has been limited to either a static deep network or a dynamic shallow network. Therefore, the development of a deep learning network that can be implemented over various time points would be the next stage in improving analysis of medical data in computer systems. The dynamic component would allow the system to investigate multiple images collected over distinct time points in an aim to assess the progress of a component of the human body. It is for this reason amongst others, that the DDBN would be of use in the analysis of medical imaging and will be one of the applications of the model once developed.

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