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A Review on Application of Deep Learning in Thermography

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ABSTRACT

Deep Learning is a new domain of Machine learning research, with the objective of moving Machine Learning closer to human minds. In neural networks, there are two sets of neurons: ones that receive an input signal and another one that send an output signal. The input layer receives an input and passes a modified version of the input to the next layer. In a deep network, there are many layers between the input and output, allowing the algorithm to use multiple processing layers, composed of multiple linear and non-linear transformations. Deep learning can be applied for image compression, image sharpening, image completion, image transformation and also in image caption research. Thermography is a study on heat distribution using infrared images. The main purpose of this paper is to review the emerging research work of deep learning on thermography.

***Keywords*--** Artificial Intelligence, Deep Learning, Thermography

I. INTRODUCTION

Deep learning is part of machine learning techniques based on learning representations of data. An observation (e.g., an image) can be represented in many ways such as a vector of intensity values per pixel, or in a more abstract way as a set of edges, regions of particular shape, etc. Some representations are better than others at simplifying the learning task (e.g., face recognition or facial expression recognition). One of the promises of deep learning is replacing handcrafted features with efficient algorithms for unsupervised or semi-supervised feature learning and hierarchical feature extraction. Various deep learning architectures such as deep neural networks, convolutional deep neural networks, deep belief networks and recurrent neural networks have been applied to fields like computer vision, automatic speech recognition, natural language processing, audio recognition and bioinformatics where they have been shown to produce state-of-the-art results on various tasks.

Deep learning (also known as deep structured learning, hierarchical learning or deep machine learning) is a branch of machine learning based on a set of algorithms that attempt to model high level abstractions in data. In a simple case, there might be two sets of neurons: ones that receive an input signal and ones that send an output signal. When the input layer receives an input it passes on a modified version of the input to the next layer. In a deep network, there are many layers between the input and output (and the layers are not made of neurons but it can help to think of it that way), allowing the algorithm to use multiple processing layers, composed of multiple linear and non-linear transformations.

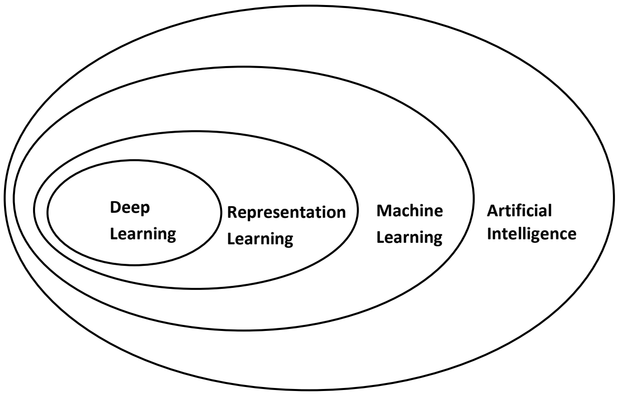

Figure 1.1 Machine Learning and AI

Deep learning is part of a broader family of machine learning methods based on learning representations of data. An observation (e.g., an image) can be represented in many ways such as a vector of intensity values per pixel, or in a more abstract way as a set of edges, regions of particular shape, etc. Some representations are better than others at simplifying the learning task (e.g., face recognition or facial expression recognition). One of the promises of deep learning is replacing handcrafted features with efficient algorithms for unsupervised or semi-supervised feature learning and hierarchical feature extraction.

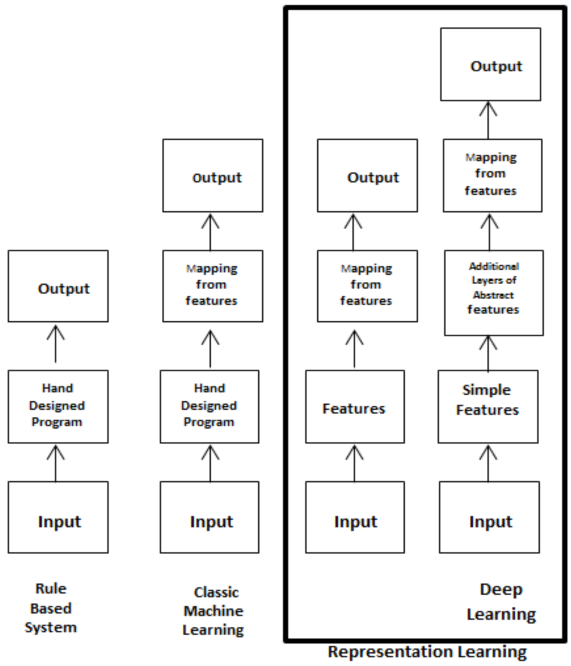

Figure 1.2 Learning multiple components

1.1 Architecture of Deep Learning

A Deep Neural Networks consists of a hierarchy of Layers, whereby each layer transforms the input data into more abstract representations (eg edge -> nose->face). The output layer combines those features into make predictions

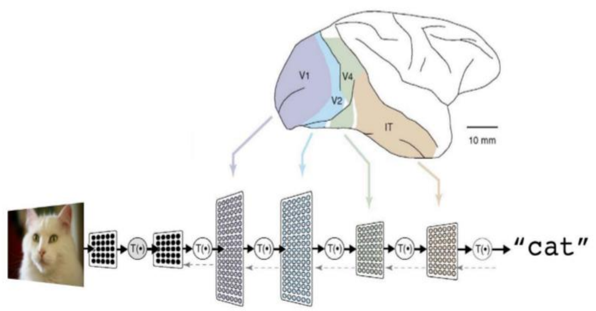

Figure 1.3Architecture of Deep Learning

Research in this area attempts to make better representations and create models to learn these representations from large-scale unlabelled data. Some of the representations are inspired by advances in neuroscience and are loosely based on interpretation of information processing and communication patterns in a nervous system, such as neural coding which attempts to define a relationship between various stimuli and associated neuronal responses in the brain. Various deep learning architectures such as deep neural networks, convolutional deep neural networks, deep belief networks and recurrent neural networks have been applied to fields like computer vision, automatic speech recognition, natural language processing, audio recognition and bioinformatics where they have been shown to produce state-of-the-art results on various tasks.

Deep learning algorithms transform their inputs through more layers than shallow learning algorithms. At each layer, the signal is transformed by a processing unit, like an artificial neuron, whose parameters are 'learned' through training. A chain of transformations from input to output is a credit assignment path (CAP). CAPs describe potentially causal connections between input and output and may vary in length – for a feedforward neural network, the depth of the CAPs (thus of the network) is the number of hidden layers plus one (as the output layer is also parameterized), but for recurrent neural networks, in which a signal may propagate through a layer more than once, the CAP is potentially unlimited in length. There is no universally agreed upon threshold of depth dividing shallow learning from deep learning, but most researchers in the field agree that deep learning has multiple nonlinear layers (CAP > 2) and Juergen Schmidhuber considers CAP>10 to be very deep learning. Deep learning exploits this idea of hierarchical explanatory factors where higher level, more abstract concepts are learned from the lower level ones. These architectures are often constructed with a greedy layer-by-layer method. Deep learning helps to disentangle these abstractions and pick out which-features-are-useful-for-learning.

For supervised learning tasks, deep learning methods obviate feature engineering, by translating the data into compact intermediate representations akin to principal components, and derive layered structures which remove redundancy in representation.Many deep learning algorithms are applied to unsupervised learning tasks. This is an important benefit because unlabelled data are usually more abundant than labelled data. Examples of deep structures that can be trained in an unsupervised manner are neural history compressors and deep belief networks.

1.2 Applicationsof deep learning

Deep Learning can be applied for Image compression.

Figure 1.4 :Deep Learning in Image compression

In the above figure Left side image is Original (1419 Kb) Centre image is compressed using neural networks (33KB), and Right side image is compressed using deep learning technique (24 KB).

Deep Learning can be used in Image sharping technique.

Figure 1.5 : Deep Learning in Image sharping

For image transformation process, deep learning can be applied.

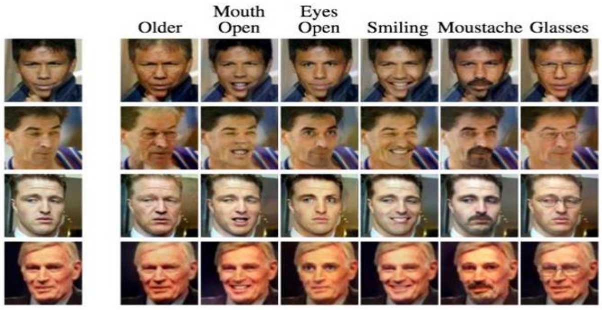

Figure 1.6 : Deep Learning in Image caption research

In image caption research deep learning can be applied. For example, if we give the following image as a input for the model, the model can give the text using deep learning. The human may give a text like "A young girl asleep on the sofa cuddling a stuffed bear". The model may give "A close up of a child holding a stuffed animal" or "A baby is asleep next to a teddy bear"

Figure 1.7: Image used for image caption Research

Google Corporation used Deep learning techniques for translating the given image text into needed language.

Figure 1.8: Quest visual acquired by Google

II. INTRODUCTION TO THERMOGRAPHY

"Thermography is a predictive maintenance technique for monitoring the condition of plant machinery structures and systems not just electrical equipment. It uses instrumentation to read infrared energy emissions (surface temperature) to determine operating conditions."Infrared thermography (IRT), thermal imaging, and thermal video are examples of infrared imaging science. Thermographic cameras usually detect radiation in the long-infrared range of the electromagnetic spectrum (roughly 9,000–14,000nanometers or 9–14 µm) and produce images of that radiation, called thermograms. Since infrared radiation is emitted by all objects with a temperature above absolute zero according to the black body radiation law, thermography makes it possible to see one's environment with or without visible illumination. The amount of radiation emitted by an object increases with temperature; therefore, thermography allows one to see variations in temperature. When viewed through a thermal imaging camera, warm objects stand out well against cooler backgrounds; humans and other warm-blooded animals become easily visible against the environment, day or night. As a result, thermography is particularly useful to the military and other users of surveillance cameras.

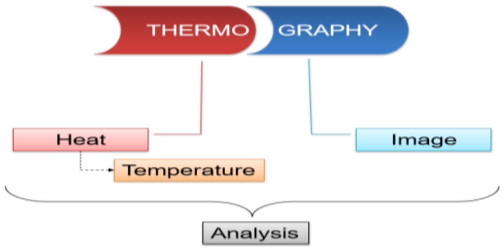

Figure 2.1: Components of Thermography

Applications of Thermography

Some physiological changes in human beings and other warm-blooded animals can also be monitored with thermal imaging during clinical diagnostics. Thermography is used in allergy detection and veterinary medicine. It is also used for breast screening, though primarily by alternative practitioners as it is considerably less accurate and specific than competing techniques. Government and airport personnel used thermography to detect suspected swine flu cases during the 2009 pandemic.

THERMOGRAPHY IN AGRICULTURE

Irrigation Scheduling Irrigation

As a consequence considerable researchers have been focusing on the use of thermal imaging or IR thermometers to schedule irrigation. A wide range of researchers that use IR thermometer imagery to schedule irrigation focuses on plant parameters such as: plant temperature and evapotranspiration rate: as well as stomatal conductance, and closing of stomata. Monitoring stomatal conductance can be a better indicator of plant response to drying soil than monitoring water potential because reductions in stomatal conductance can occur even before any change in plant water status.

Soil Salinity Detection

Soil Salinity Detection Soil salinity causes severe environmental degradation that impedes crop growth and overall regional production Soil salinity information can be extracted from thermal imageries as emitted radiance can provide subsoil information that reflected radiation cannot. Thermography coupled with adequate software clearly shows the effect of salinity on the potted plants, and this effect was maintained for over 30 days thus the author states that thermography can be an early useful method to diagnose saline stress in potted plants. Therefore thermal Infrared (TIR) radiation is important for salinity studies.

THERMOGRAPHY IN INDUSTRIAL APPLICATIONS

Thermal imaging has evolved into one of the most valuable diagnostic tools for industrial applications. By detecting anomalies often invisible to the naked eye, thermography allows corrective action to be taken before costly system failures occur. Thermal imaging cameras have become compact systems that look just like a normal video camera/digital camera, are easy to use and generate a real-time high-resolution image. Numerous industries worldwide have discovered the advantage of incorporating thermal imaging cameras in their industrial programs**.**

Low voltage inspections

Thermal imaging cameras, are commonly used for electrical inspections. As electrical connections become loose, there is a resistance to current that can cause an increase in temperature. This can then cause components to fail, resulting in unplanned outages and injuries. In addition, the efficiency of an electrical grid becomes low prior to failure, thus energy is spent generating heat, causing unnecessary losses**.**

High voltage inspections Power

Temperatures of the cooling fins and the high voltage connections can be compared so that, if necessary, corrective action can be taken before real problems occur. Other high voltage installations that are checked with a thermal imaging camera include circuit breakers and switchers and high-voltage power lines. Potential problem areas will be clearly shown in the thermal image.

Pipework Infrared

Thermography is also a great tool for detecting faults in pipes and insulation. Heat exchangers are regularly checked with infrared to detect blocked pipes. An thermal imaging camera can quickly give an overview of the entire installation. There is no need to check each pipe individually.

The use of Thermal Imaging in Medical and Veterinary Applications

Healthcare is not only about treating disease and injury; it is also about protection, detection and prevention. In recent years there has been a rapid growth in the medical thermal imaging industry to monitor the sick, elderly, disabled and otherwise at risk person without physical contact and without intruding on his or her privacy. The same thermal imaging technology is now used by the Veterinarian to detect problems in animals prior to the development of complications and more serious injury.

Medical Applications

Thermography is non invasive, non contact equipment that uses the heat from a body to aid in making diagnoses of a number of healthcare conditions. It is completely safe and uses no radiation. Although operating in real time, the imagers are able to store many images which can be retrieved for subsequent analysis. Imagers are in use in hospitals, medical centers, surgeries and by individual practitioners including physiotherapists. The main categories of current applications are:

Breast pathology

The use of the thermal imager as a screening tool in the detection of breast cancer was a controversial topic when first introduced due to the environmental control requirements; it has now gained scientific acceptance however, and is proving to be a powerful tool in the battle against cancer and other diseases.

Circulation problems

Thermal imaging may help in the detection of the presence of deep vein thromboses and other circulatory disorders in the lower limbs. There is a rapidly increasing list of other applications in the medical and dentistry fields, such as the detection of nerve damage, differentiation of headaches and dental decay to name a few.

III. APPLICATION OF DEEP LEARNING IN THERMOGRAPHY

Image processing is a technique used to improve the quality of image and image mining is a technique to find out some hidden information in the images. We can apply deep learning on thermal images to find some hidden information in the infrared images.

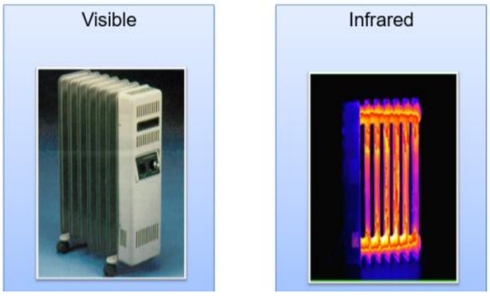

Figure 3.1 : visible and infrared images of inverter

For example, in the above figure the radiator is grey-white color on a blue backgroud. The radiator is grey-white because its surface reflects these components of white light from the projectors. An infrared camera also uses colors to present the thermal world it sees. The big difference is colors in an infrared image express both reflection and emission. Emission of heat comes from the material itself. Reflection comes from what is placed in front. Emission and reflection are complementary. Instead of using the temperature data to predict the fault in the inverter, we can use thermal images to predict the fault using deep learning.

Deep Learning can be applied to find the condition of running car. The infrared image of a running car can be captured on the road. So far we used the camera images of running cars to calculate the speed of car. We can use infrared camera images of car to find out the condition of car, temperature inside the car, running time of the car using deep learning.

Figure3.2: Infrared image of a car

In the above figure the infrared image of a running car is capture using thermal camera fixed on a road. In the image, darker means cooler and brighter means warmer area of the car. By applying deep learning methods we can predict whether the car may fire during running or not. Deep learning can be applied to diagnosis the fault in the thermal machines. In the normal vision camera it is not easy to find out the problems in the machine. But by using deep learning we can easily diagnosis a problem.

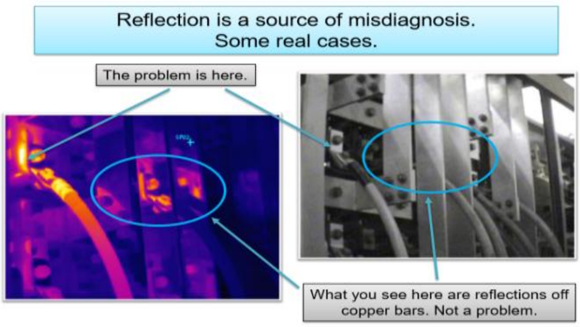

Figure 3.3: diagnosis of fault in a machine

In the above figure the problem is actually in wire. But we cannot identify the problem with usual camera. If we use thermography we may also find the problem in both wires and copper bars. But the actual problem is occurred in wires only. With the deep learning technique we can easily diagnosis the actual problem in a machine.

IV. CONCLUSION

The initial success of deep learning is in automatic speech recognition, natural language processing, image processing. In this study I proposed a model to predict the running condition of a car using deep learning techniques. Deep learning techniques give more accurate results than the usual learning algorithms.

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