Knowledge-Based Systems 102 (2016) 51–63

Contents lists available at ScienceDirect

Knowledge-Based Systems

journal homepage: www.elsevier.com/locate/knosys

Image matting in the perception granular deep learning

Hong Hu*, Liang Pang, Zhongzhi Shi

Key Laboratory of Intelligent Information Processing, Institute of Computing Technology, Chinese Academy of Sciences, Beijing, China

ARTICLE INFO

Article history:
Received 29 April 2015
Revised 19 March 2016
Accepted 21 March 2016
Available online 8 April 2016

MSC:
00-01
99-00

Keywords:
Image matting
Deep learning
Granular computing
Graph embedding
Granular deep learning

ABSTRACT

In the past decade, proposed by Geoffrey Hinton, deep learning has been proved its powerful ability in processing data from lower level to higher level and gradually composes more and more semantic concepts by unsupervised feature learning for single modalities (e.g., text, images or audio). Usually a multi scale pyramid structure is applied in a layered deep learning neural network. But how to design a multi scale pyramid structure is still an open problem. At the same time, granular computing (GrC) has been an active topic of research in machine learning and computer vision. In this paper, inspired by the original insight of granular computing proposed by Zadeh, a generalized image-matting approach is defined in the framework of a novel Granular Deep Learning(*GDL*), in which the information similarity, proximity and functionality are very important for feature learning. We show that layered deep learning can be formally represented as a framework of a granular system defined by fuzzy logic. In this way, the pyramids or hierarchical structure of a layered deep learning neural network can be easily designed in such a granular system, i.e., the convolution pyramids or hierarchical convolutional factor analysis in the deep learning can be viewed as special cases of granular computing. The experiments show the effectiveness of our approach in the task of foreground and background separating.

1. Introduction

Images' foreground and background separating is still an open problem. According to Levin A et al. [1], image matting tries to classify pixels of an image into foreground and background. Pixels distribute in an image in a scaled texture way. The structure of textures or objects are determined by the local distribution structure of image's pixels, so the local structure of samples' distribution is significant for foreground and background separating. Granular computing is widely used in the images' processing and classification. Image matting is a sound task to demonstrate the ability of a scaled or pyramidal layered granular computing approach. According to [2], histogram thresholding based, neuro-fuzzy based, neighborhood based and clustering based approaches are four granular computing techniques widely used in the images' processing and classification. For example, [3] used granular computing in an interactive colour video segmentation; [4] tried to use spherical granular computing in the color image segmentation; for pixels clustering, fuzzy c-means (FCM) and fuzzy k-means (FKM) use the semantic meaningful constructions of individual pixels drawn together based on their proximity (location) to construct information granules [5,6]. Recently, the notion of three-way decisions (3WD) is again proposed by Hamido Fujita and Tianrui[7] for the ideas of trisecting a universal set and designing most effective and appropriate strategies for processing the three regions are a common human practice in problem solving.

In this paper, a modified formal definition of leveled perception granular system based on tolerance relation has been proposed by us. The concept of perception granular deep Learning was firstly proposed by us in [8]. We show that above mentioned approaches can be unified in the concept of perception granular deep Learning(*GDL*). The experiments show *GDL* has high ability to increase the texture information entropy and improve the effect of foreground and background separating. The approach of perception granular deep learning hybridizes the concepts of granular computing and layered deep learning.

Nowadays the learning of multilayer neural networks becomes a huge wave of technology trends for big data and artificial intelligence, e.g., the famous deep learning approach. The term deep learning has gained much attraction in the mid-2000s after a publication by Geoffrey Hinton [9]. Deep networks characterized by hierarchical computing have been successfully applied to unsupervised feature learning for single modalities (e.g., text, images or audio) [10]. Deep learning simulates the hierarchical structure of human brain, processes data from lower level to higher level, and gradually composes more and more semantic concepts. But how to design the structure of layered deep learning is still an open

* Corresponding author. Tel.: +861018910760062.
E-mail addresses: huhong@ict.ac.cn (H. Hu), pangliang@qq.com (L. Pang), shizz@ics.ict.ac.cn (Z. Shi).

http://dx.doi.org/10.1016/j.knosys.2016.03.018
0950-7051/

problem. In most papers, the size of the convolution kernel, the size of a neural layer and the number of layers are decided by a series of trials. Only very few papers try to use rules from experience to estimate the this problem, for example, Xudong Cao [11] has tried to use two constrains in the design of deep structure to guarantee the performance gain when going deep. In this paper, for the task of visual perception, the methodology of intuitive granular computing (GrC) is applied to help the design of a layered neural network for deep learning.

The granular computing (GrC) has been an active topic in machine learning and computer vision over the same decade of deep learning. In the IEEE-GrC 2006 conference, the outline of *GrC* is defined as a general computation theory for effectively using granules such as classes, clusters, subsets, groups and intervals to build an efficient computational model for complex applications with huge amounts of data, information and knowledge [12]. In 2012, Lin pointed out that Granulation seems to be a natural methodology deeply rooted in human thinking. Many daily things are routinely granulated into sub-things [13]. For more, the granular computing, dealing with inexact, uncertain, or vague information, can help cluster ensemble to deal with inherent complexities in unsupervised classification learning by generating a large pool of different clustering solutions and then combining them into a final decision [14].

Just as Zadeh [15], in 1997, pointed out that there are three basic concepts that underlie human cognition: granulation, organization and causation. Informally, granulation involves decomposition of whole into parts; organization involves integration of parts into whole; and causation involves association of causes with effects. Granulation of an object A leads to a collection of granules of A, with a granule being a clump of points (objects) drawn together by indistinguishability, similarity, proximity or functionality. Zadeh's point can help us to design the structure of a layered deep learning.

The policy of granular computing can be proposed by further analyzing the main points of Zadeh's original insight of GrC. The policy says:

Objects are hierarchically distributed, such kind hierarchically distribution can be represented by trees, and in every level, objects from same class are located in a connected region.

For example, videos can be classified as sports, news and stories etc., any concrete video can be segmented according to its scenario modes, and pixels of an image in a video segment can be clustered into foreground and background objects. Such kind leveled trees' structures can be created according to indistinguishability, similarity and proximity of samples and described by r-cut sets of fuzzy functions. We denote such kind r-cut sets as "granules" of a granular system. For more, feature vectors of all levels' samples or granules can be leveled calculated upon granules by fuzzy logical functions. We denoted such kind computing as "granular computing".

From the relevant literature, it is easy to see that many GrC researches focus on classification and clustering [16–18]. Zhang and Zhang [18,19] used the quotient space theory to study indistinguishability and similarity. Yao [20] extended the equivalent class to rough approximation set. The quotient space structure described by equivalence relations is used to probe the structure of granules such as classes, clusters, subsets, groups etc. In a more general way, Lin [21,22] and Yao [23,24] used binary relations and neighborhood systems to study indistinguishability and similarity respectively, the geometric concepts: partitions, covering and topology, and neighborhood can be described by binary relations in the algebra. Originally, these relations were described by distance functions.

In 2012, Pedrycz A et al. defined a granular system on fuzzy sets and discussed several operations and their granular consistency [25]. In fact, layered neural systems used by deep learning have close relation with fuzzy logic. For neural systems, the basic logic processing module to be used as a building module in the logic architectures of neural networks comes from OR/AND neurons [26,27], also referred by [28]. The ideal of hybrid design neural networks and fuzzy logical systems is firstly proposed by [29]. While neural networks and fuzzy logic have added a new dimension to many engineering fields of study, their weaknesses have not been overlooked, in many applications the training of a neural network requires a large amount of iterative calculations. Sometimes the network cannot adequately learn the desired function. Fuzzy systems, on the other hand, are easy to understand because they mimic human thinking and acquire their knowledge from an expert who encodes his knowledge in a series of if/then rules [30]. For more, a reasonable explanation for the apparent success of the layer-wise training strategy for Deep Belief Networks (DBN) is that unsupervised pre-training helps to mitigate the difficult optimization problem of deep networks by better initializing the weights of all layers [31].

Just as Yao [32] pointed out that "a conceptual formulation emphasizes on the meaning and interpretation of the concepts and notions of the theory, whereas a computational formulation focuses on procedures and algorithms for constructing these notions". The indistinguishability, similarity and proximity of samples are in the side of computing, at the same time, along the layered computing of a deep learning, more concepts about objects can be found, and the knowledge of these concepts can be used to classify the input samples, and so a hybrid designing approach which combines learning and fuzzy logical knowledge design of a granular system can be used.

Based on these opinions, in this paper we try to embed distance functions in fuzzy logical formulas to define granular systems, and the fuzzy logical described granular system is used to design the structure of a layered deep learning. The leveled perception granular system in this paper contains two parts-(1). leveled structure, which uses granules to describe indistinguishability and similarity among samples ; (2). granular computing, which computes feature vectors for classification. In the task of images' understanding, the leveled structure is just the multi scale image processing structure which focuses an image from pixels to whole image; and the granular computing tries to extract features of images by fuzzy logical functions. The corresponding learning procession of a deep learning is divided into two stages . In the first stage, we design a fuzzy granular system as the structure of a layered deep learning according to the fuzzy knowledge about a concrete task. At the second stage, a novel learning approach of granular system is applied. This approach uses a hybrid method which combines fuzzy logical designing, proximal support vector machine classifiers (PSVM) [33], back propagation and intrinsic graph technique in the learning processing of a multi layered neural network for the purpose of perception or image understanding. This novel approach gives a new focus on deep learning, and make the structure designing of deep learning under the help of fuzzy logic possible. So in this paper, we denote the concept of granular learning as "granular deep learning(*GDL*)" and the corresponding granular system, which can be viewed as the structure of a deep learning is denoted as "Perception Granular System".

To generalize original image matting approach under the framework of multi scale granular layered deep learning and to design the structure of a layered deep learning under the help of granular computing are two main purposes of this paper. The main contributions of this paper include:

- Our novel granular system gives a new focus for deep learning. It is the first time that fuzzy logic is introduced for leveled feature abstraction in a deep learning; We try to simplify the designing of a layered deep learning's structure by abstracting