Convolutional Layer Aggregation using LSTM

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Paper ID ***

Abstract. The abstract should summarize the contents of the paper and should contain at least 70 and at most 300 words. It should be set in 9-point font size and should be inset 1.0 cm from the right and left margins. ...

1 Introduction

In recent years, Convolutional Neural Networks (CNNs) have shown remarkable advantage on computer vision tasks like image classification[]. The basic architecture of convolutional layer consists of two levels, feature extraction and feature mapping. In feature extraction level, the input of each convolutional neuron is connected to local receptive domain and the local characteristics are extracted. Feature mapping level employs multiple convolutional kernels to focue on diferent aspects of the characteristics. The results of each convolutional layer are customarily regarded as features containing spatial and channel-wise information. A series of convolutional layers are stacked together to expand the field of reception and to generate higher level features. The evolution of CNNs from LeNet[] to DenseNet[] increase both the performance and the size of the network, which yields deeper and wider network structures.

From the first application in ResNet[], skip connections have been introduced into CNN structures, and proven effective in various vision tasks. Skip connections combine the output of previous layer and the current layer, dealing with the gradient vanishing problem. DenseNet[] connects densely in a block to make better use of previous features. To further utilize features from different layers, Yu[deep layer aggregation] extends the current skip connection approach proposes deep layer aggregation architectures. These architectures simply combine features of different level by concatenation or addition, without considering the interior relationship between low-level and high-level feature representations.

Recurrent Neural Networks (RNNs)[] has been proposed to deal with sequantial data like text or speech. Different from feedforward neural networks, RNNs build connections between nodes which are in the same layer. RNNs can be unfolded as a directed graph along the time steps, with all the layers sharing the same weights. This makes RNNs applicable to sequential tasks such as text classification. Long Short Term Memory (LSTM)[] is a special RNN, which makes use of three gates to select valuable information from all the memories. LSTM has proven to be more efficient than normal RNNs in most tasks on sequences.

In this work, we investigate a brand new approach to convolutional layer aggregation, by introducing a new architecture which is named as '*Concolutional*

Neural Networks-Recurrent Aggregation' (CNN-RA). Our goal is to aggregate outputs of multiple layers and retrieve more expressive features. To achieve this, we build CNN-RA by building parallel connection between a CNN and a LSTM. Features from lower Convolutional layers to higher layers naturally form a sequance with a variety of information. This kind of sequence contains both the features themselves and the transformation relationship between different features, which directly leads us to RNNs. We crearte information between outputs of convolutional layers and the inputs of LSTM, and employ the outputs of LSTM as the final feature for tasks such as image classification.

The receptive fields and feature maps sizes of different convolutional layers vary from each other, especially for two layers with a pooling layer inside. We propose an algorithm to transform different shape of feature matrixes to vectors with the same dimention. Then transformed vectors are stacked together as inputs of LSTM. The number of chosen features is the step lengh of the LSTM.

The development of new network architectures is always a time consuming task with abundant hyper parameters to determine. Previous work on layer aggreegation such as DLA[] brings with huge change on the original network architecture, which can even be much more complicated. However, our proposed CNN-RA won't do any modification on the original network, by only connecting it with a parallel LSTM. This property enable CNN-RA easily applicable to multiple convolutional network structures.

Our evaluation experiments extends famous network structures VGG[] and ResNet[] for standard image classification dataset. The testing results show improvements across different network structures and datasets. The connected LSTM brings with higher performance without increasing much parameter count. The experiment processes show that the relationship between two convolutional blocks with a down sampling layer inside has the most important contribution to the model.

2 Related Work

3 Methodology

4 Training Details

5 Results

6 Conclusion

7 Paper formatting

7.1 Language

All manuscripts must be in English.

7.2 Paper Length

The submission page length is 14 pages for content plus maximum two pages for references. Over-length papers will simply not be reviewed. This includes papers where the margins and formatting are deemed to have been significantly altered from those laid down by this style guide. The reason such papers will not be reviewed is that there is no provision for supervised revisions of manuscripts.

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It is imperative that the paper ID is mentioned on each page of the manuscript. The paper ID is a number automatically assigned to your submission when registering your paper submission on CMT.

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8 Blind Review

Many authors misunderstand the concept of anonymizing for blind review. Blind review does not mean that one must remove citations to one's own work—in fact it is often impossible to review a paper unless the previous citations are known and available.

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Saying "this builds on the work of Lucy Smith [1]" does not say that you are Lucy Smith, it says that you are building on her work. If you are Smith and Jones, do not say "as we show in [7]," say "as Smith and Jones show in [7]" and at the end of the paper, include Reference 7 as you would any other cited work.

An example of a bad paper:

An Analysis of the Frobnicatable Foo Filter

In this paper we present a performance analysis of our previous paper [1], and show it to be inferior to all previously known methods. Why the previous paper was accepted without this analysis is beyond me.

[1] Removed for blind review

An example of an excellent paper:

An Analysis of the Frobnicatable Foo Filter

In this paper we present a performance analysis of the paper of Smith and Jones [1], and show it to be inferior to all previously known methods. Why the previous paper was accepted without this analysis is beyond me.

[1] Smith, L., Jones, C.: The frobnicatable foo filter, a fundamental contribution to human knowledge. Nature **381** (2005) 1–213

If you are making a submission to another conference at the same time, which covers similar or overlapping material, you may need to refer to that submission in order to explain the differences, just as you would if you had previously published related work. In such cases, include the anonymized parallel submission [**?**] as additional material and cite it as

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> We describe a system for zero-g frobnication. This system is new because it handles the following cases: A, B. Previous systems [Zeus et al. 1968] did not handle case B properly. Ours handles it by including a foo term in the bar integral.
>
> The proposed system was integrated with the Apollo lunar lander, and went all the way to the moon.

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This is an edited version of Springer LNCS instructions adapted for ACCV 2018 full paper submission.

You will have to use LaTeX2$_\varepsilon$ for the preparation of your final (accepted) camera-ready manuscript together with the corresponding Springer class file `llncs.cls`.

We would like to stress that the class/style files and the template should not be manipulated and that the guidelines regarding font sizes and format should be adhered to. This is to ensure that the end product is as homogeneous as possible.

9.1 Printing Area

The printing area is 122 mm × 193 mm. The text should be justified to occupy the full line width, so that the right margin is not ragged, with words hyphenated as appropriate. Please fill pages so that the length of the text is no less than 180 mm.

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Use 10-point type for the name(s) of the author(s) and 9-point type for the address(es) and the abstract. For the main text, use 10-point type and single-line spacing. We recommend using Computer Modern Roman (CM) fonts, Times, or one of the similar typefaces widely used in photo-typesetting. (In these typefaces the letters have serifs, *i.e.*, short endstrokes at the head and the foot of letters.) Italic type may be used to emphasize words in running text.

Bold type and underlining should be avoided.

With these sizes, the interline distance should be set so that some 45 lines occur on a full-text page.

Headings. Headings should be capitalised (*i.e.*, nouns, verbs, and all other words except articles, prepositions, and conjunctions should be set with an initial capital) and should, with the exception of the title, be aligned to the left. Words joined by a hyphen are subject to a special rule. If the first word can stand alone, the second word should be capitalised. The font sizes are given in Table 1. (Note that vertical lines are not common table components anymore.)

Table 1. Font sizes of headings. Table captions should always be positioned *above* the tables. A table caption ends with a full stop.

Heading level	Example	Font size and style
Title (centered)	**Lecture Notes ...**	14 point, bold
1st-level heading	**1 Introduction**	12 point, bold
2nd-level heading	**2.1 Printing Area**	10 point, bold
3rd-level heading	**Headings.** Text follows ...	10 point, bold
4th-level heading	*Remark.* Text follows ...	10 point, italic

Here are some examples of headings: "Criteria to Disprove Context-Freeness of Collage Languages," "On Correcting the Intrusion of Tracing Non-deterministic Programs by Software," "A User-Friendly and Extendable Data Distribution System," "Multi-flip Networks: Parallelizing GenSAT," "Self-determinations of Man."

Lemmas, Propositions, and Theorems. The numbers accorded to lemmas, propositions, theorems, and so forth should appear in consecutive order, starting with the number one, and not, for example, with the number eleven.

9.3 Figures and Photographs

Please produce your figures electronically and integrate them into your text file. For LaTeX users we recommend using package `graphicx` or the style files `psfig` or `epsf`.

Check that in line drawings, lines are not interrupted and have constant width. Grids and details within the figures must be clearly readable and may not be written one on top of the other. Line drawings should have a resolution of at least 800 dpi (preferably 1200 dpi). For digital halftones 300 dpi is usually sufficient. The lettering in figures should have a height of 2 mm (10-point type). Figures should be scaled up or down accordingly. Please do not use any absolute coordinates in figures.

Figures should be numbered and should have a caption which should always be positioned *under* the figures, in contrast to the caption belonging to a table, which should always appear *above* the table. Please center the captions between the margins and set them in 9-point type (Fig. 1 shows an example). The distance between text and figure should be about 8 mm, the distance between figure and caption about 5 mm.

If possible (e.g. if you use LaTeX) please define figures as floating objects. LaTeX users, please avoid using the location parameter "h" for "here". If you have to insert a pagebreak before a figure, please ensure that the previous page is completely filled.

9.4 Formulas

Displayed equations or formulas are centered and set on a separate line (with an extra line or halfline space above and below). Displayed expressions should be numbered for reference. The numbers should be consecutive within each section or within the contribution, with numbers enclosed in parentheses and set on the right margin. For example,

$$\psi(u) = \int_o^T \left[\frac{1}{2} \left(\Lambda_o^{-1} u, u \right) + N^*(-u) \right] \mathrm{d}t \ . \tag{1}$$

Please punctuate a displayed equation in the same way as ordinary text but with a small space before the end punctuation.

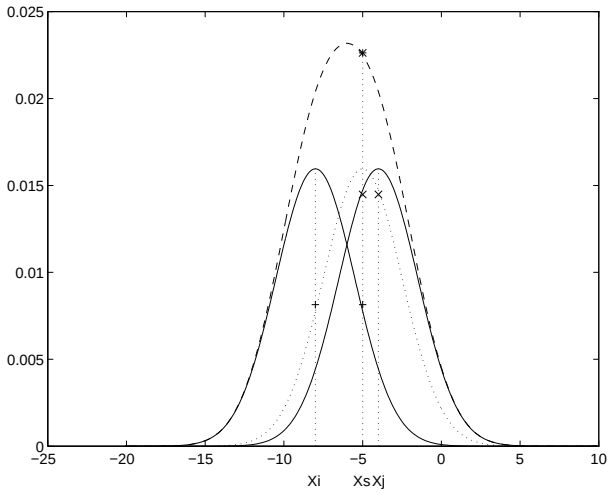

Fig. 1. One kernel at x_s (*dotted kernel*) or two kernels at x_i and x_j (*left and right*) lead to the same summed estimate at x_s. This shows a figure consisting of different types of lines. Elements of the figure described in the caption should be set in italics, in parentheses, as shown in this sample caption. The last sentence of a figure caption should generally end without a full stop

9.5 Program Code

Program listings or program commands in the text are normally set in typewriter font, for example, CMTT10 or Courier.

Example of a Computer Program

```
program Inflation (Output)
  {Assuming annual inflation rates of 7%, 8%, and 10%,...
   years};
   const
     MaxYears = 10;
   var
     Year: 0..MaxYears;
     Factor1, Factor2, Factor3: Real;
   begin
     Year := 0;
     Factor1 := 1.0; Factor2 := 1.0; Factor3 := 1.0;
     WriteLn('Year  7% 8% 10%'); WriteLn;
     repeat
       Year := Year + 1;
       Factor1 := Factor1 * 1.07;
       Factor2 := Factor2 * 1.08;
       Factor3 := Factor3 * 1.10;
```

```
        WriteLn(Year:5,Factor1:7:3,Factor2:7:3,Factor3:7:3)
    until Year = MaxYears
end.
```

(Example from Jensen K., Wirth N. (1991) Pascal user manual and report. Springer, New York)

9.6 Footnotes

The superscript numeral used to refer to a footnote appears in the text either directly after the word to be discussed or, in relation to a phrase or a sentence, following the punctuation sign (comma, semicolon, or full stop). Footnotes should appear at the bottom of the normal text area, with a line of about 2 cm in TEX and about 5 cm in Word set immediately above them.[1]

9.7 Citations

The list of references is headed "References" and is not assigned a number in the decimal system of headings. The list should be set in small print and placed at the end of your contribution, in front of the appendix, if one exists.

Please do not insert a page break before the list of references if the page is not completely filled. Citations in the text are with square brackets and consecutive numbers, such as [**?**], or [**?**,**?**].

10 Conclusions

The paper ends with a conclusion.

[1] The footnote numeral is set flush left and the text follows with the usual word spacing. Second and subsequent lines are indented. Footnotes should end with a full stop.