Development of Teaching-Learning Contents for AI Core Principles at the Elementary School Level: With a Focus on Convolutional Neural Network

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Abstract

With the rapid development and multifarious application of artificial intelligence technology, elementary learners are demanded to learn about AI. At the same time, due to the pandemic, classes without face-to-face contact have been increasing. This study aims to develop teaching-learning contents instructing core principles of artificial intelligence, respectively in face-to-face and non-face-to-face learning environments. Proposed teaching-learning contents mainly target elementary learner and provide simplified experience for convolutional neural network (CNN) algorithm. Learners accomplish convolution operation with simple numbers then extract feature map. Students experience CNN process with 5x5 virtual input image consists of numbers. 2x2 filter is given for convolution operation, and students fill 4x4 feature map with the results. These same teaching-learning activities can be also offered with online interactive worksheets, using ‘LIVEWORKSHEETS’ website. By transforming printed worksheets into online ones, learners in distance learning classes can accomplish identical coursework clicking and typing then score themselves. Teachers and learners can choose appropriate teaching-learning way or mix both of them flexibly based on their situation. Subsequent studies are expected to revise the contents after sufficient pilot classes with diverse learner groups and devise additional physical teaching-learning activity suitable for elementary learners. This study proposes the importance of continuous research on artificial intelligence education for young learners and versatile teaching-learning contents for various learning environment.

Keywords

AI Education, Convolutional Neural Network, Non-face-to-face Education, Elementary Education, Computational Thinking.
Introduction

For many in the next generation, artificial intelligence (AI) will be an often overlooked, magical force that powers their lives much as electricity, the internal combustion engine, and networking technology power ours. Software and AI education is becoming more important competency for students in line with the recent social changes called the 4th Industrial Revolution. Countries around the world are devoting efforts to foster AI talent of school-aged children for upcoming new era. Nevertheless, core principles of AI are so abstract that most of elementary students need tangible and simple ways of teaching-learning. Learners are not able to see for themselves how AI processes input data, so it is important for teachers to organize education program with similar practical experience. This is a starting point of teaching-learning contents in this paper.

On the one hand, the importance of distance learning is increasing recently. In the aftermath of COVID-19, many schools are offering online classes. Public education had been rooted on group teaching-learning in physical infrastructure such as schools. Thus, educational deficits and gaps deteriorated as face-to-face learning classes in schools suddenly had become impossible. Both teachers and learners are familiar with video classes nowadays, but still most of the materials are shared in one direction. Not only real-time communication, but also real-time educational participation and feedback are significant for this problem. Developing online interactive worksheet would be one of the solutions.

This paper starts with core principles of Convolutional Neural Network (CNN) and the worldwide mainstream of distance learning class since COVID-19 outbreak, then proposes two different formats of worksheet with identical teaching-learning activities for instructing CNN algorithms to elementary learners.

Related Research

Convolutional Neural Network (CNN) has been successfully applied for multiple image tasks such as classification, detection and many other. Especially CNN has been considered as the first solution to address classification problems. Numbers and characters were recognized through the pre-learned CNN structure. The attractive feature of CNN is its ability to exploit spatial or temporal correlation in data. CNN consists of a sequence of layers, and each CNN layer transforms one activation volume to another through a differentiable function. The topology of CNN is divided into multiple learning stages composed of a combination of the convolutional layers, non-linear processing units,
subsampling layers. In convolutional layers, convolution operation is performed. As [Figure 1] shows, filter executes convolution operation with input data and produces output data.

Convolution operation requires basic arithmetic ability of multiplication and addition. In case of national curriculum in Republic of Korea, 2nd graders in elementary school are expected to calculate multiplication of digits. Nevertheless, continuous and repetitive calculations confuse young learners so that teachers should consider cognitive development stages of learners before actual classes.

On the other hand, with COVID-19 spreading across the world, many countries have used various medium to provide distance education. [Figure 2] is about method of giving distance courses by schools in 199 countries. The survey shows that elementary and secondary schools provided Internet-based online classes the most. The results conclusionally suggest most of learners including elementary school students are competent to use Internet for distance learning and teachers need to develop varied online teaching-learning materials.
Results

In order to teach professional and sophisticated skills to elementary school students, in addition to simply regulating the difficulty, they should present ways to increase students' participation and encourage interest. Teaching-learning program for CNN consists of 3 hours of successive classes including several academic activities such as experiencing online drawing tools, implementing pooling with the drawn feature map, self and peer assessments. Among them, this paper mainly introduces an activity based on printable or online worksheet.

Face-to-face class means traditional education format based on direct explanation from teachers and printable worksheets. In this program, teachers show familiar examples of CNN and discuss further application of the technique with students at the beginning of the class. Then teachers explain what CNN is and how it works, with various visual materials such as video clips. The goal of this worksheet is to make students think and act like AI and realize themselves how CNN operates. Figures below show the main part of worksheet for the content, executing convolution operation.

![Figure 3](http://www.webology.org)

**Figure 3.** Example of 5x5 Virtual Input Image Input for AI

**Step 1**: Check the virtual input image given to AI. The image is represented as table filled with numbers.

[Figure 3] is an example of 5x5 virtual input image for AI, which consists of numbers 0 to 4. These small numbers would help elementary learners calculate without complex arithmetic operation. Furthermore, the arrangement of the numbers considered drawing feature map and performing pooling process subsequently. Considering elementary teachers have to design every worksheet as simple as possible, this whole set of numbers draws only whole numbers after pooling process. Otherwise, elementary learners may struggle with divisions end up with decimal fraction and miss the authentic goal of the class. Meanwhile, pooling can be addressed in subsequent teaching-learning contents.
Step 2: Check a sample filter and size of feature map for convolution operation.

Convolution operation in CNN requires filter. AI treats numerous huge data efficiently since original input images are gradually reduced by the filter. Size of the filter can be larger but 2x2 filter like [Figure 4] has given for this content because this teaching-learning method targets elementary learners. Also, there are two 0 so that learners only need to multiply the first number by 2, and plus the last number which multiplied by 1. The results of convolution operation fill feature map one by one. [Figure 5] is an example of feature map in CNN. By convolution operation, 4 numbers are merged in a certain number. As a result, 5x5 virtual input image produce 4x4 feature map. 6 in the sample feature map suggests how to perform convolution operation.
Step 3: Comprehend how to execute convolution operation by a sample calculation.

CNN process in this worksheet is simple as possible and the calculation required for drawing feature map is easy enough for 5th and 6th graders. Nevertheless, convolution operation is unfamiliar way to calculate for elementary learners and many of them may be confused with the correct order of the operation. It is necessary for teachers to demonstrate how filter works with the virtual input image with gradational and repetitive performance before students’ attempts.

[Figure 6] suggests the students how to explain convolution operation. Cells in same positions are colored with same colors. Students multiply a number filled with certain color in virtual input image by a number filled with the same color in filter. Finally, add up all 4 results and write the number in the exact position in feature map. Then repeat the operation until fill all the cells of the feature map.

With 4x4 feature map, students are supposed to manage the operation for 16 times. If it takes too much time for them, this step can be implemented by group works. For instance, assuming there is a group of 4 students, each of them handles the operation only 4 time.

Step 4: Fill feature map and check the answers.

All students would be end up with drawing same feature map according to this worksheet. They can compare their results with co-learners and check the right answer with teachers.

Step 5: Find out how the process done with the worksheet related with the actual AI CNN process.

During the correction, the whole classroom is bound to be mingled feelings of joy and frustration. However, the purpose of this content is not filling all the cells in time, nor calculating without errors. Teachers should remind students that they have experienced indirectly how CNN works. Thus, teachers can encourage students who could not finish the task, if they have understood the process correctly.

Some students may raise questions that how feature map helps AI to recognize input images. CNN repeats convolution operation and draws feature maps until it gains smaller data advantageous enough to store. AI uses the data for deciding what an input image is. The more data AI accumulated, the more accurate classification will. Refocusing on the purpose of the worksheet is important for achieving academic goals of the content.
With an increase of non-face-to-face class all over the world due to Pandemic, demand of non-contact online teaching-learning methods is rapidly increasing. Since then, teachers have been trying to develop or utilize efficient educational tools for non-face-to-face or online classes.

LIVEWORKSHEETS(www.liveworksheets.com) is an online site for making online educational worksheets. Users can create online interactive worksheets or workbooks based on various question formats, and these can be shared with worldwide users. Teachers can transform an image of printable worksheet to an interactive online worksheet. By sharing URL, students can do the worksheets themselves and send their answers to the teachers. They can find out the results if teachers entered correct answers previously.

![Figure 7. Online Worksheet for Convolution Operation](image)

![Figure 8. Sample Result of Self-Correction](image)

In this content, students in non-face-to-face educational environment attempt convolution operation based on teacher’s explanation and guide. The online worksheet, including 5x5
virtual input image with numbers and 2x2 filter, is identical with printable one, and the only difference is the way to insert answers. Students can type number in each cell like [Figure 7]. Then students self-correct the result immediately by pressing ‘Finish!’ button. [Figure 8] shows how interactive worksheet created from LIVEMARKETS helps students to check their understanding for CNN without facial contact with teachers. Students also can send their answers to the teacher by email.

Other teaching-learning activities including explaining concept and principles of CNN and demonstrating convolution operation can be done same as face-to-face class. One is also able to mix both offline and online methods for the most effective teaching-learning.

**Conclusion**

The AI core principles teaching-learning contents proposed in this paper provide an opportunity for elementary learners to easily experience CNN algorithms, especially convolution operation. At the same time, the contents suggest printed worksheets can be converted into online interactive worksheets, providing same educational tasks regardless of learning environment. The teaching-learning contents are mainly targeting elementary learners, but these can be widely applied to middle and high school students or adult learners who do not have prior knowledge. Lifelong education and liberal arts lectures with more elaborate explanation of the actual algorithms are other promising fields for application. Moreover, by sharing the URL of the online worksheet, learners and teachers around the world can experience the contents and discuss further updates together.

However, these teaching-learning contents only revolve around convolution operation from CNN algorithms and have not yet undergone sufficient class demonstration in the actual educational field. Evaluations and revisions based on various pilot classes would be necessary. Considering developmental stages, additional physical activities for review would be also effective for elementary learners. We hope diverse learners have an opportunity to be interested in AI, as well as to cultivate the capabilities and knowledge required in the upcoming new era.

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