Handwritten mathematical symbols OCR

2023-1 인공지능과딥러닝 – 6조

Term-project 주제 발표

PREM

Precision Rotating Electromechanical Machine Lab.

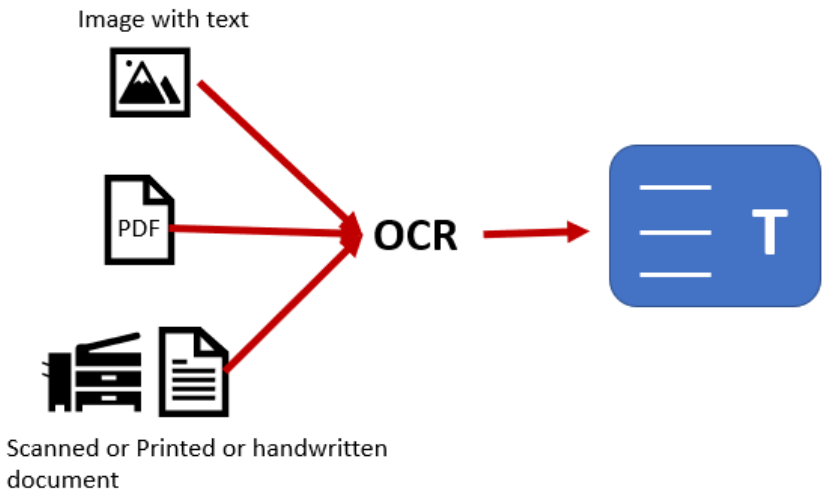
I. Background

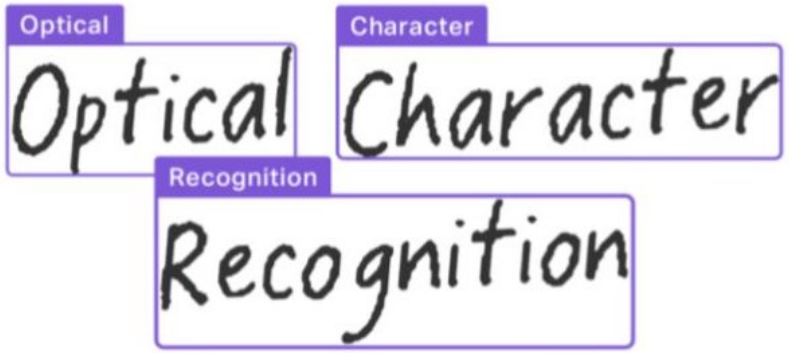
Optical character recognition (OCR)

- Handwritten text, Printed text → Machine-encoded format (digital form)

- OCR technology
  - Automation of text conversion
  - Text conversion into searchable information

- OCR technology 활용 사례
  - Papago - 이미지 번역 서비스
  - 주민등록증, 사업자등록증 등 행정문서 처리 자동화
  - 물류 시스템 자동화





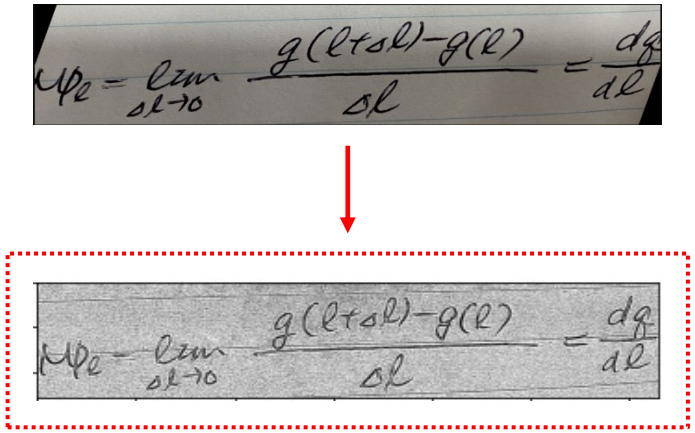
Examples of OCR technology

- **OCR system**
  - Extraction of features
  - Classification of features (based on patterns)

Mathematical symbols OCR

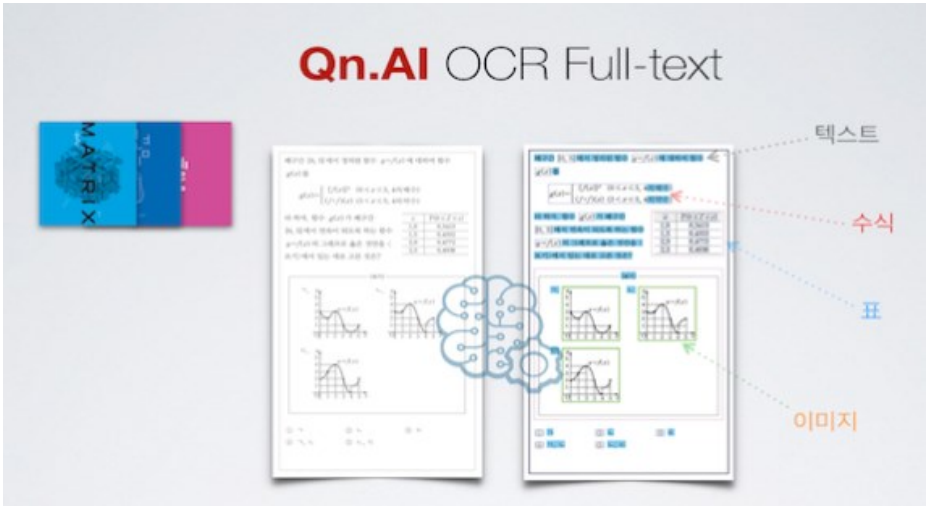
- **일렬로 정렬된 문자가 아닌 수식을 Recognition**
  - Printed 된 수식을 지원하는 상업용 OCR 프로그램
  - 교육 현장 등 넓은 분야에 활용 가능

- **Handwritten mathematical symbols OCR**
  - 인식 정확도가 높지 않아 상업적 활용이 부진함
  - 회전, 필체 등 내-외부적 Noise가 존재하여 보다 정교한 이미지 전처리가 요구됨



Example of preprocessing

Flow chart of mathematical symbols OCR



Commercial mathematical symbols OCR program

II. Related works

Handwritten mathematical symbol OCR

- Handwritten equation을 인식하는 OCR을 아동용 교육용 로봇에 적용한 선행 연구 존재
- 해당 연구에서는 0-9까지의 Digits 및 사칙연산과 같은 Basic expression에 국한하여 인식을 수행
- 이미지 전처리의 경우 MATLAB *graythreshold* library를 활용함

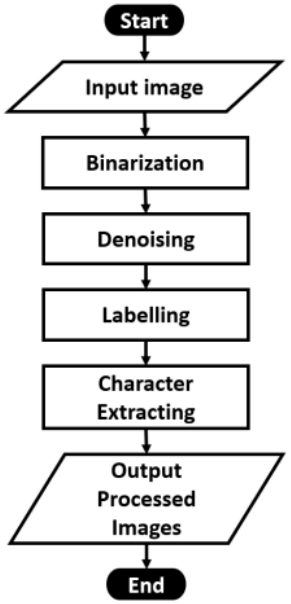


Fig. 2 Image Segmentation Flowchart

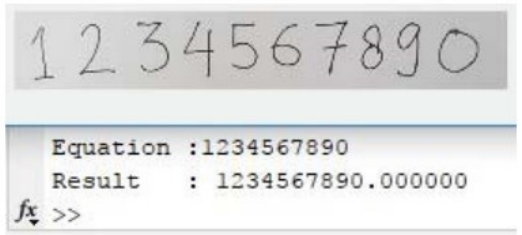


Fig. 16 Testing for Sample Image 1

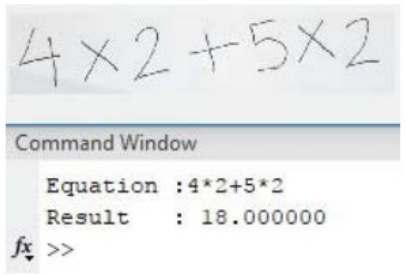


Fig. 17 Testing for Sample Image 2

Flow chart and result

2018 IEEE 8th International Conference on System Engineering and Technology (ICSET 2018), 15 – 16 October 2018, Bandung, Indonesia

Optical Character Recognition for Handwritten Mathematical Expressions in Educational Humanoid Robots

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***Abstract*— Humanoid robots are seen as perfect education partners for students these days. Many researchers are working on educational humanoid robots to make them more effective in educating students. One of many approaches to realize it is to make the robots educate children in two-way communication. In this case, robots can recognize students' progress and provide suitable learning materials according to their progress. In a simple scenario for basic mathematics learning, the robot educates a student on how to solve mathematical expressions. As the student understand the concepts, the robot gives some simple exercises to further improve student's ability. While completing the exercise, the partner robot supervises each mathematical expression solved by the student, acknowledges mistakes and provides correct solutions. Thus, the robot must be equipped with a system which can recognize mathematical expressions and give the solutions. Such system is an inherent foundation to build much smarter robots in delivering education to students. This paper covers detail design and implementation of the system which recognizes handwritten mathematical equations and provides the corresponding solutions. Testing results show that the system performs quite well with 97.4% accuracy with slight errors for characters with similar shapes.**

***Keywords*— Educational humanoid robot, neural network, optical character recognition, handwritten mathematical expression.**

I. Introduction

Humanoid robots have been seen as a futuristic educational companion for children to date. Humanoid robots were studied and evaluated in programming learning application at schools which is covered in [1]. Another similar implementation described in [2] in which the robots provide fun learning and quizzes for students. Humanoid robots are also harnessed in conducting elementary language education in [3].

Humanoid robots are perceived as good educational companions if they can educate students in two-way interaction. This means that the robots are capable of asking and answering questions with the students. Such education method is believed to be more effective than the conventional teaching method.

There are lots of applications on educational robots for physics and mathematics learning [3]. To realize the two-way learning process between robots and students, robots must be designed to be able to recognize handwritten characters. In this paper, we provide an implementation of a system which recognizes handwritten mathematical expressions and solves for the mathematical solutions. These abilities allow the robots to recognize students' handwritten equations and interact with the students to find solutions. Therefore, two-way interaction in learning mathematics and physics is practical using this system.

In the real application, the system is in form of software embedded in a computer inside the humanoid robot. It requires robots' eye camera to capture handwritten equations on students' paper. In order to be fully functional for educational purposes, the system must be integrated into the whole humanoid robot system to realize social interaction mechanism with students. This paper covers detail implementation in software point of view. Image processing, neural networks, and equation solver principles are used to construct the system, which will be covered in detail in the following section.

In this paper, we will focus on mathematical expressions which include numbers (0-9) and basic operators (+, −, ×, ÷) only. We consider that numbers and basic operators are the most important mathematical symbols that are used in mathematics learning. Equation solver for more complex mathematical expressions can be covered as future improvement of this research project.

II. System Design

The whole system comprised of three main entities (image segmentation, character recognition, and equation solver). Firstly, the robot's camera captures a handwritten mathematical equation on a paper. The captured image is then processed in the image segmentation subsystem. This process includes extracting each character from the complete equation and preprocessing them, which produces several images for each character. Those images are then further processed in the character recognition subsystem. Every character is recognized in this subsystem and then stored in an array. This array is now recognized as a complete equation by the computer. Lastly, the equation solver subsystem finds for mathematical solution of the equation. The block diagram of the proposed system can be found in Figure 1. Every subsystem will be discussed in detail in the following sections.

Fig. 1 System Overview

A. Image Segmentation Subsystem

This subsystem is responsible for extracting each character image from a bigger image containing a complete

978-1-5386-9180-9/18/$31.00 ©2018 IEEE 178

Related paper

Referenece : Lee, Jhonson, Bobbi Winema Yogatama, and Hans Christian. "Optical character recognition for handwritten mathematical expressions in educational humanoid robots." *2018 IEEE 8th International Conference on System Engineering and Technology (ICSET).* IEEE, 2018.

III. Methodology & dataset

Data augmentation

- Dataset의 Noise를 줄이기 위하여 최대한 숫자, 배경만을 남기는 Adaptive threshold를 이용

Character extraction

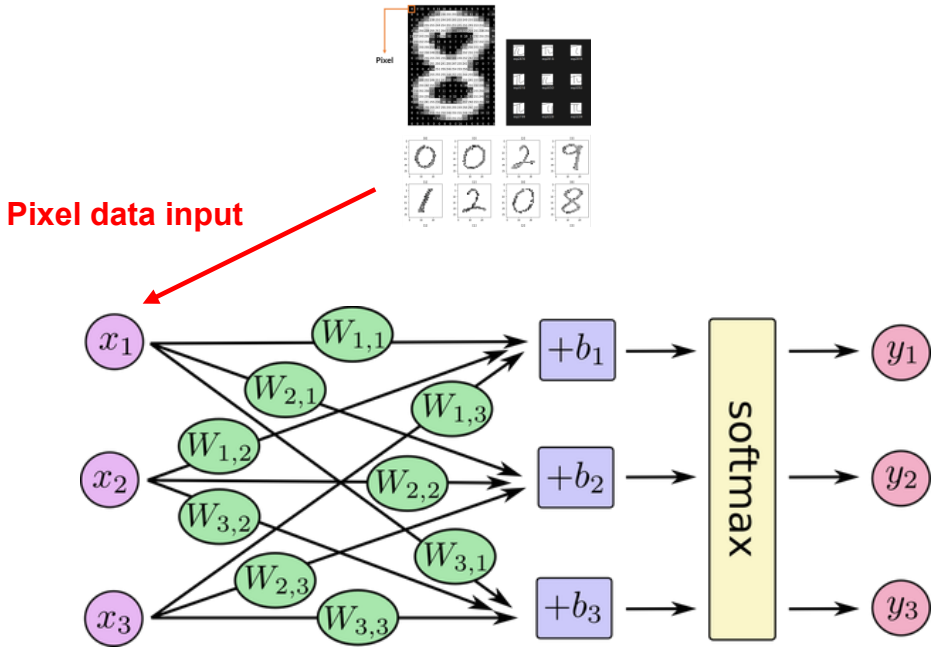
- Dataset에서 추출한 Mathematical symbol을 Softmax regression을 사용하여 학습

Hyperparameter tuning

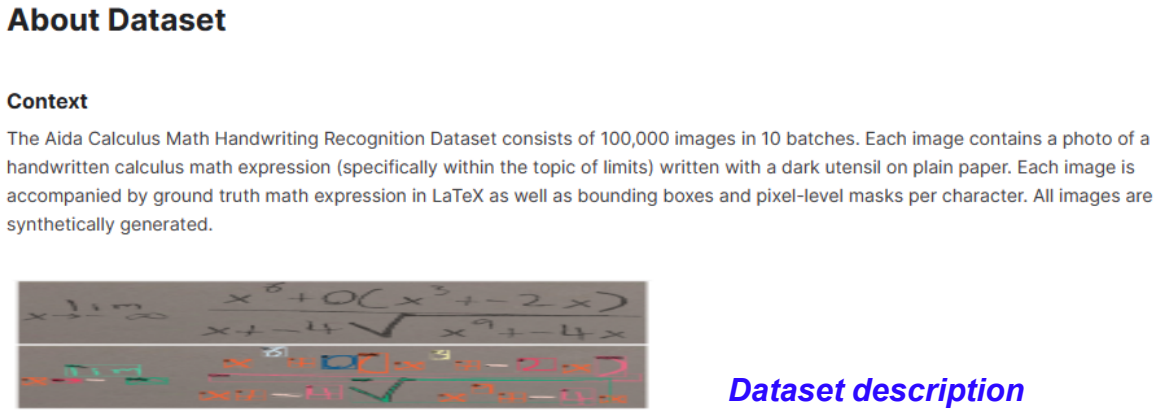
- 최적 Optimizer 선정, penalty function 개선 등을 함께 고려

Dataset

- Kaggle의 'Handwritten math symbol dataset' 활용 예정
- 학습 Data가 부족하다고 판단될 경우, 'Aida calculus math handwriting recognition dataset' 등을 활용하여 보완 예정



Softmax regressor

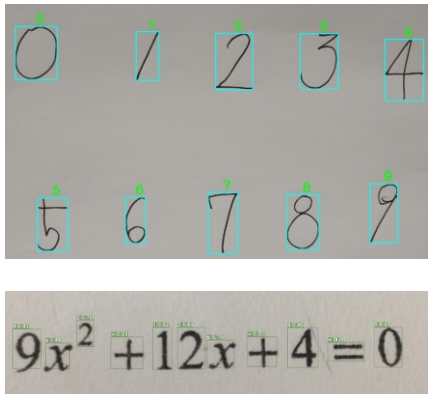


Dataset description

IV. Expected effectiveness

More complex expression

- 지수, 미적분 등이 포함된 다양한 수식을 인식하여 Text로 출력 가능
- 수식이 다수 포함된 논문 등의 Text 작성 자동화를 통하여 보다 효율적인 문서 작업이 가능할 것으로 예상됨



Input image data
(OpenCV)

Math symbol
OCR

$$9x^2 + 12x + 4 = 0$$

Output text

Expected effectiveness

Q&A