The Flatteners

EECS 504, Fall 2020

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Executive Overview

- Folded and bent paper when scanned can be very difficult to read

- Our idea is to:
  - Flatten folded sheets of paper using deep learning and transfer learning
  - Generate answer keys for math worksheets using template matching and K-means clustering
  - Incorporate a web-app as a visual aid of the dataset and worksheet grading
    - Demo at the end of presentation

Background and Impact

- COVID-19 has affected the education industry deeply
- Teachers are grading homework assignments, such as math worksheets, via images sent by the student instead of in-person
- Students may not necessarily submit perfectly flat sheets and instead can be folded or creased

Computer Vision Methods

- Deep Learning and Transfer Learning

- Dataset Generation
  - Creates 3D distorted paper sheets
  - Realistic lighting and shadows

- Answer Key Generation
  - Template matching
  - K-means clustering to tease out individual numerical problems

Prototype

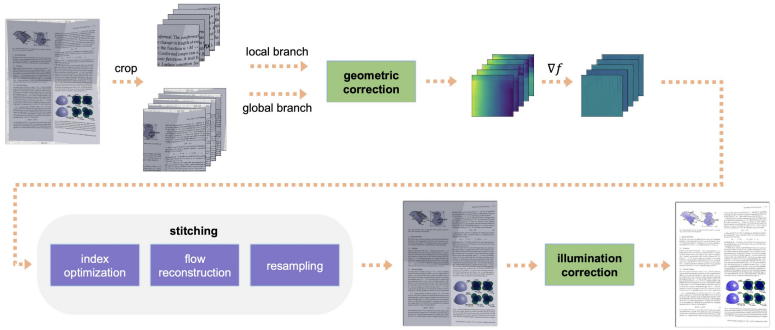
- Dataset Generation Examples
  - 3D distorted mesh developed by perturbing random vertices
  - Used these meshes to generate 2D flow maps
  - Introduced Plotly lighting for realistic lighting and shadows to highlight the folds and creases as compared to existing datasets
  - Applied worksheet image on to different backgrounds
  - Mask image generated to represent boundaries of perturbed worksheet image against the background

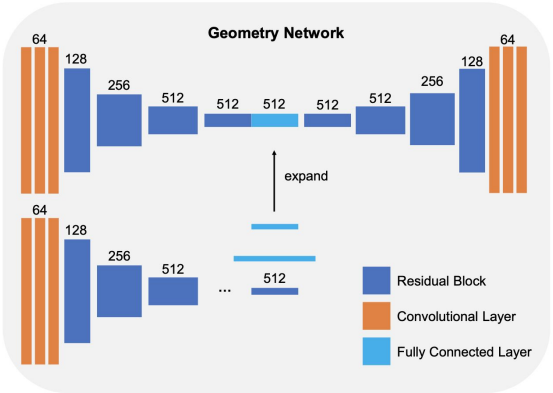
Prototype - Model Architecture

Model Training

- Input: Local and Global Image Patches
- Output: 2D Estimated Flow Maps
- Loss Function:

$$\mathcal{L}(F_s, F_t) = \frac{1}{HW} \sum_p ||F_s(p) - F_t(p)||_2$$

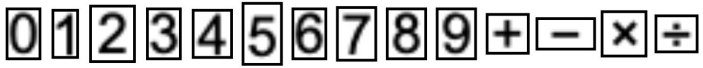




Figures and architecture adapted from the following source:
Xiaoyu Li, Bo Zhang, Jing Liao, and Pedro V. Sander. Document rectification and illumination correction using a patch-based cnn, 2019.

Prototype

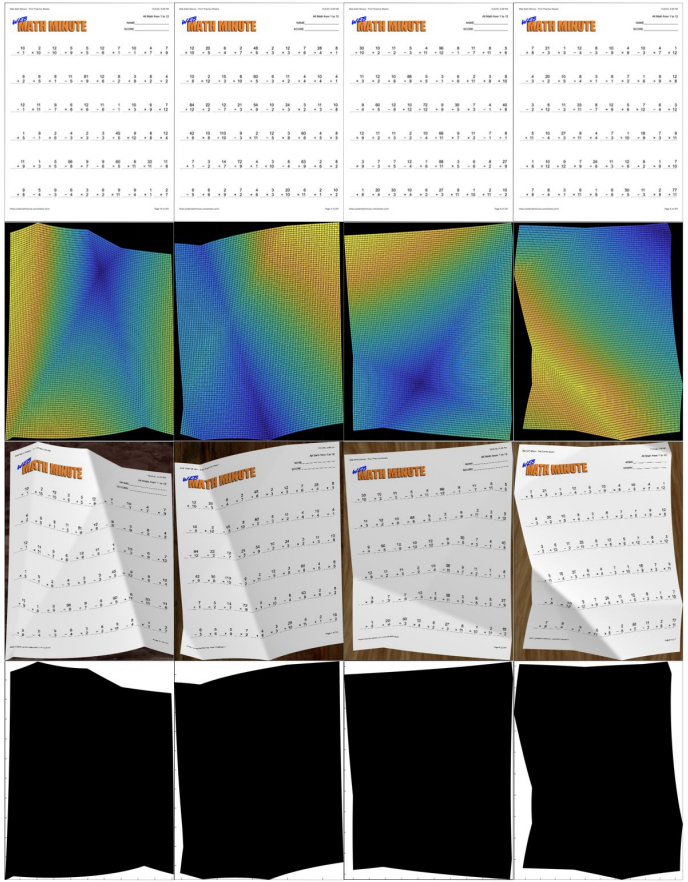
- Answer Key Generation
  - Template matching for individual digits and math symbols while avoiding duplicate detections using a mask image



  - K-means clustering for each problem
    - Initiated algorithm to search for 60 distinct clusters as there are 60 different problems in each math worksheet

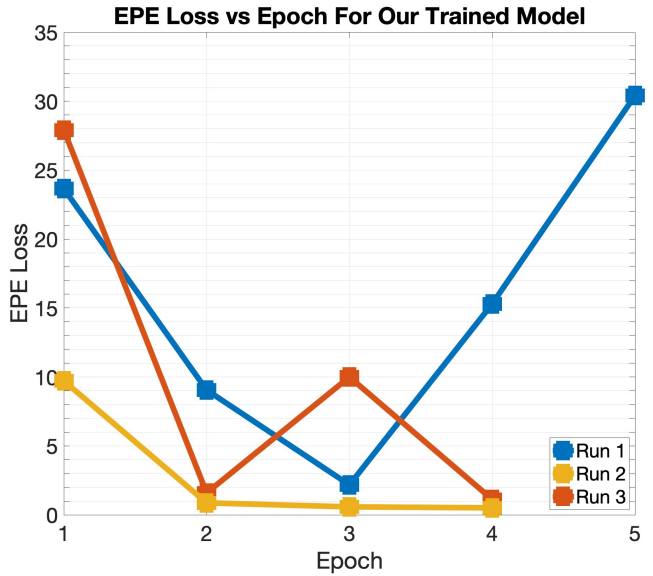
Results - Data Generation

- Produces realistic 3D distorted sheets as seen in the third row
- Lighting and shadows are realistic
- Quick and efficient process due to using batch



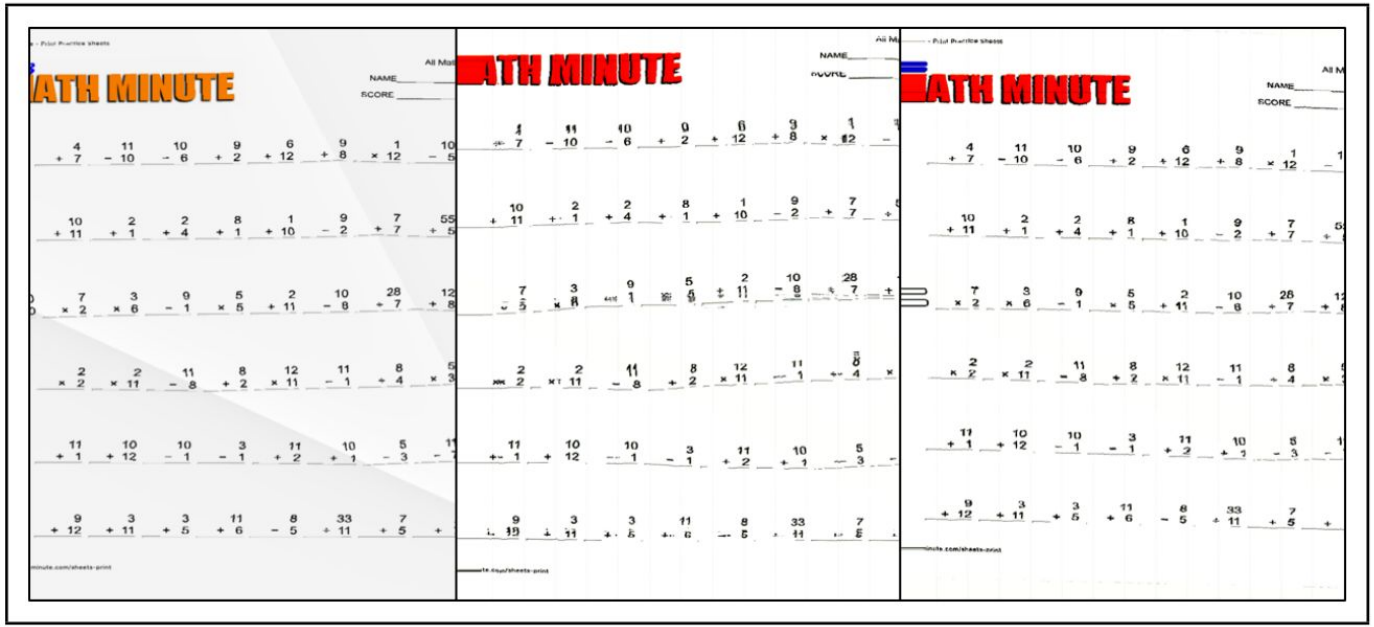
Results

- Utilizing U-Net architecture
- Multiple data sets were generated at different specifications *(resolution factor, size, & test train data split)* and used to train the network
- To the right you can see three runs. Optimal loss achieved at Run 2 epoch 4 with a **Loss of 0.51**



Run	Epochs	Patch (px)	L-Rate	Res Factor	Training/Test Split (%)	Min. EPE Loss
1	5	128	0.001	4	70/30	2.17
2	4	64	0.01	6	80/20	0.51
3	5	64	0.001	4	80/20	1.12

Results



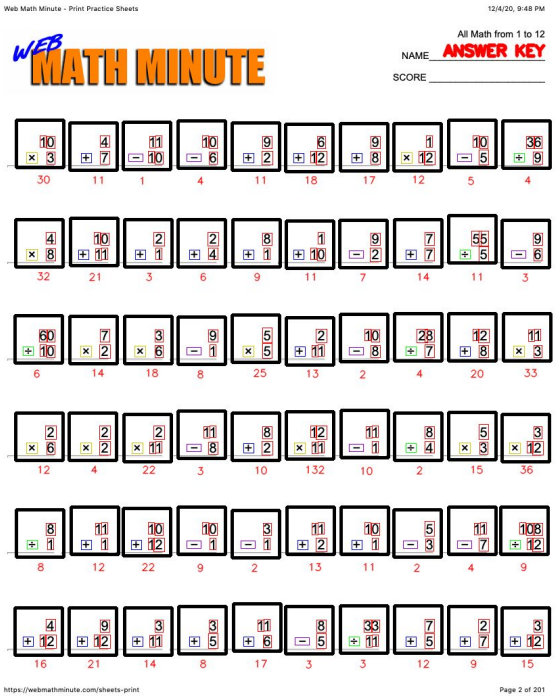
Original Perturbed Image

Output of Our Trained Model **Loss = 0.51**

Output of Pre-Trained Model

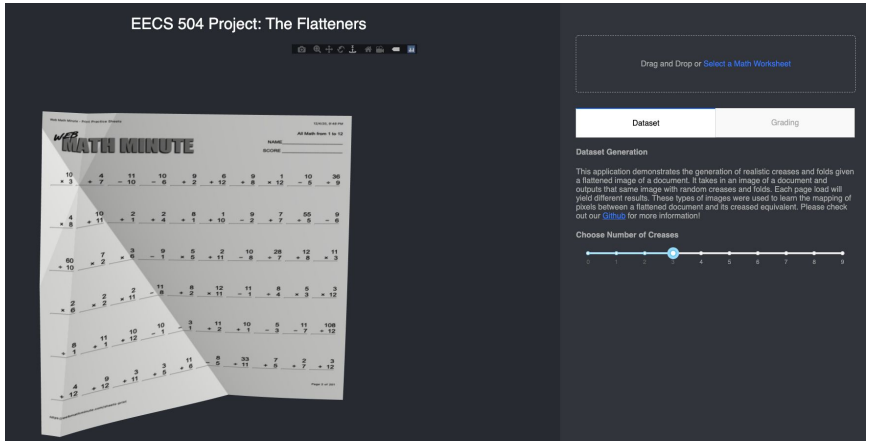
Answer Key Generation Performance

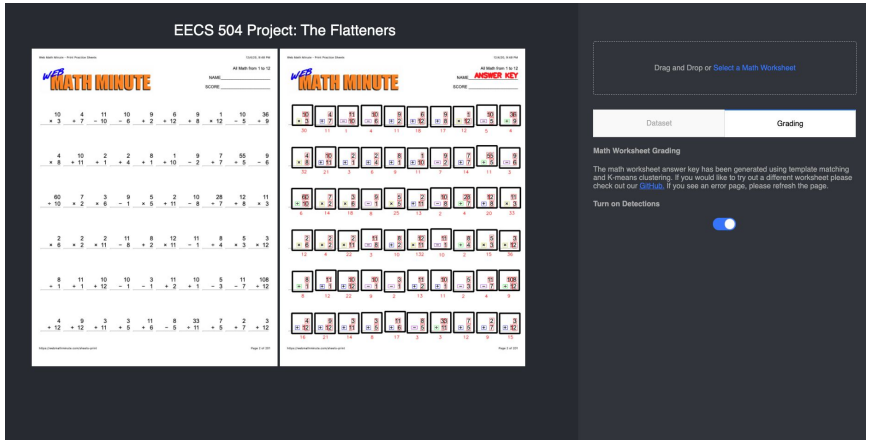
- Template matching requires significant tuning
- Our setup works most of the time
- K-means clustering also requires tuning for proper clustering but still works most of the time
- If unsatisfactory clustering is produced, a custom Error page is shown



Web-App

This demonstration application was created using the Dash/Plotly framework and was deployed using Heroku. All code was generated in python and adapted for use in the web application.





Thank you,
Professor Corso
Oscar de Lima
& Parker Koch
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