University of Idaho
College of Engineering

UI DATA SCIENCE COMPETITION

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FOR: ECE504-172

CONVEX OPTIMIZATION AND DATA ANALYSIS

SCOPE

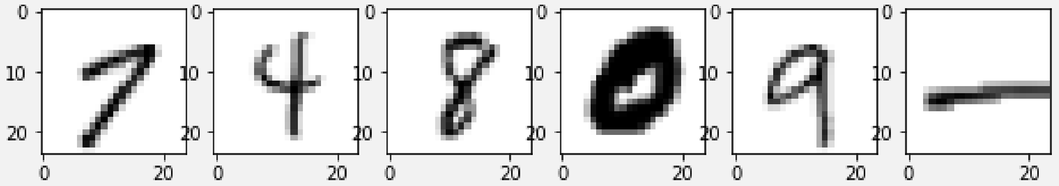
- Introduction
- Data Description
  - Training Set
  - Testing Set (Arithmetic Expressions for Grading)
- Neural Networks
  - Loss Function
  - Gradient Descent
  - Stochastic mini-batch GD
  - Convolutional Neural Nets and other Optimizers
- Results
- Conclusion

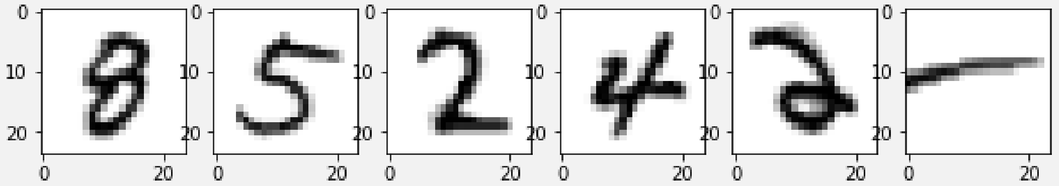
TASK DESCRIPTION

- UI Data Science Competition
- Correctly grade mathematical expressions
  - arithmetic sums and subtractions.
- Train using digits and arithmetic operators.
- Use the trained model to grade mathematical expressions accurately.
- The data was provided by the competition organizers and was available on the competition web-page
- https://dscomp.ibest.uidaho.edu/

DATA (TRAINING)

- Digits from 0-9 and arithmetic operators ‘+’, ‘-’, and ‘=’
- Classes assigned from 0-9 and 10, 11, & 12, respectively.
- A total of 13 classes
- The correct class labels were provided as numbers
- Converted to one-hot vectors



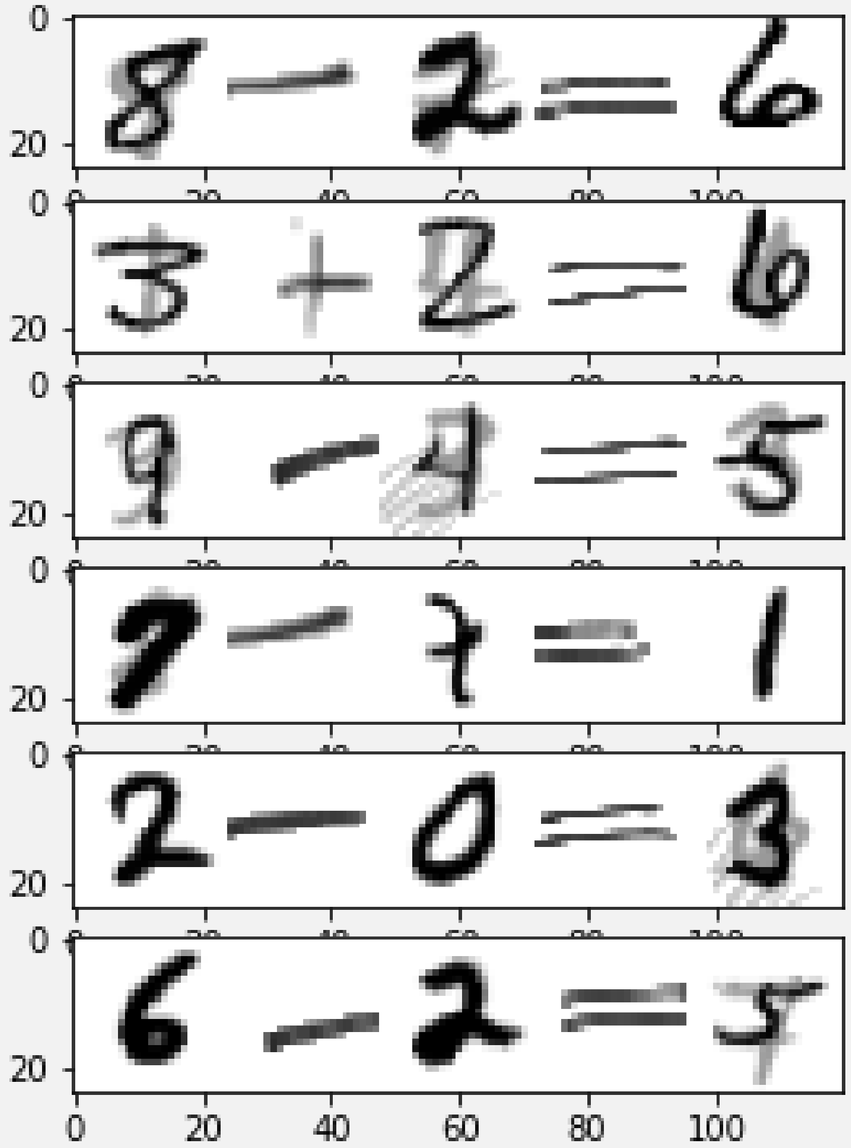


Number (Class)	Image Representation	Outputs												
		d_0	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}
0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1	1	0	1	0	0	0	0	0	0	0	0	0	0	0
2	2	0	0	1	0	0	0	0	0	0	0	0	0	0
3	3	0	0	0	1	0	0	0	0	0	0	0	0	0
4	4	0	0	0	0	1	0	0	0	0	0	0	0	0
5	5	0	0	0	0	0	1	0	0	0	0	0	0	0
6	6	0	0	0	0	0	0	1	0	0	0	0	0	0
7	7	0	0	0	0	0	0	0	1	0	0	0	0	0
8	8	0	0	0	0	0	0	0	0	1	0	0	0	0
9	9	0	0	0	0	0	0	0	0	0	1	0	0	0
10	+	0	0	0	0	0	0	0	0	0	0	1	0	0
11	-	0	0	0	0	0	0	0	0	0	0	0	1	0
12	=	0	0	0	0	0	0	0	0	0	0	0	0	1

DATA (TESTING)

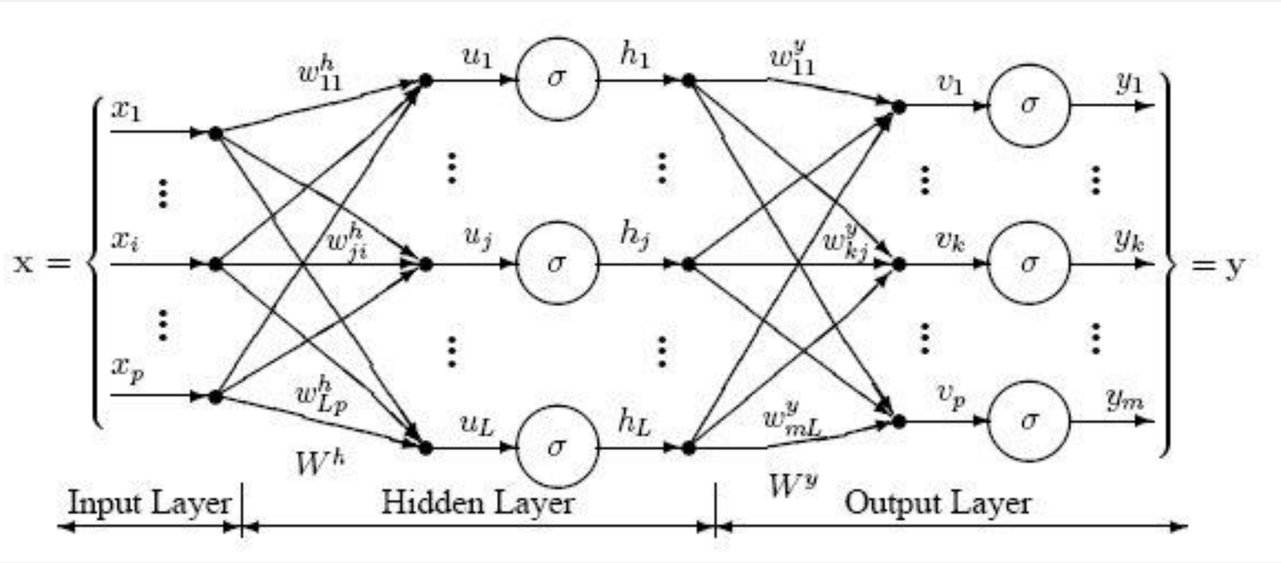
- Mathematical expressions
- In the forms
  - a+b=c
  - a-b=c
  - a=b+c
  - a=b-c
- Some correct (e.g. 5=4+1) and some wrong (5-3=1)
- Based on the trained model, grade correct as 1 and grade wrong expression as 0

EXAMPLES OF EXPRESSIONS



USING NEURAL NETWORKS

- Contain an input layer, an output layer and multiple hidden layers
- The output at each stage is the sum of the weighted inputs passed through an ‘activation function’
- Backpropagation to optimize the weights with gradient descent (GD)
- Inputs are gray levels
- Outputs equal number of classes
- Convolutional layers



https://www.dtreg.com/solution/view/21

MINI-BATCH STOCHASTIC GD (SGD) APPROACH

- Apply the GD approach to mini-batches of data
- The total dataset (epoch) is:
  - randomly shuffled
  - split into batches of size N
  - The GD method is applied to each batch
- For training, we leave 20% for validation
- The cross-entropy is used due to the soft-max activation at the last layer (outputs probabilities)
- $softmax\left(x_n | x_n \in x = [\, x_1, \ldots, x_n, \ldots, x_N]\right)$

$$= \frac{e^{-x_n}}{e^{-x_1} + e^{-x_2} + \cdots + e^{-x_n} + \cdots e^{-x_N}}$$

TESTING STRATEGY

- We know that images 1, 3 and 5 are digits
- So, for any given test image
- $Digit\ n = \arg\max P_{nm}^{O}, m = 0, \ldots, 9$
- $Operator\ n = \arg\max P_{nm}^{O}, m = 10, \ldots, 12$
- Take care of some other cases
- Make sure that the expression is correct
- Four cases: equal on position ‘2’ or ‘4’, ‘+’ or ‘–’ the other operators
- Grade ‘0’ if wrong and ‘1’ if correct

RESULTS

- Best accuracy of 98.86%
- Using 2 convolutional layers and 1-layer neural network as a classifier with ADAM optimizer
- Gradient Descent alone gave up to 94% accuracy with 3-layers
- Momentum with CNN gave up to 96% accuracy
- ADAM with FCNN gave around 96% accuracy whereas three Convolutional layers and 1-3 FCNN gave around 98% accuracy
- The best accuracy came with augmentation
- CNN (3x3x36) + max. pooling (2) + CNN (3x3x48) + max. pooling (2) + CNN (3x3) + 12x288 + 288 x13

CONCLUSION

- Participated in the UI Data Science Competition as the course project
- Used neural nets, CNN’s and various optimizers to classify and grade math quizzes correctly
- Focused on different optimizers for the course
- A best accuracy of 98.86% using augmented data

FUTURE WORK

- See how to get 1.0!!!
- Actual accuracy for just 20,000 equations was 99.41% (achieving this is a goal)
- Use an external server or GPU to try more complex networks
- Larger output channels in the CNN and apply dropout or batch normalization
- Try more sophisticated forms of augmentation

THANK YOU AND QUESTIONS