# Stroke Based Posterior Attention for Online Handwritten Mathematical Expression Recognition

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# Outline

① Introduction

② Proposed methods

③ Experiments

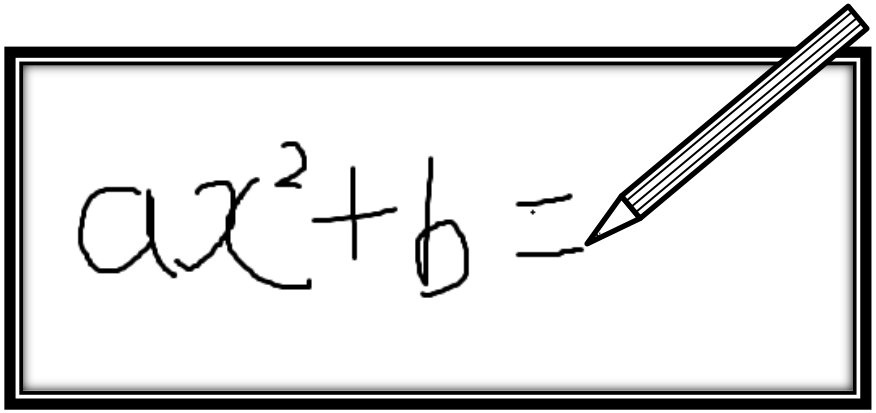
④ Conclusion

# Introduction

**Online Handwritten Mathematical Expression Recognition (OHMER)**

INPUT

handwritten trajectory points



OUTPUT

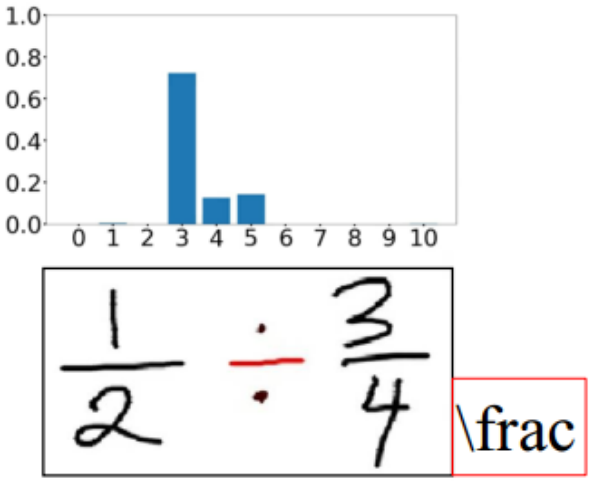
LaTeX strings

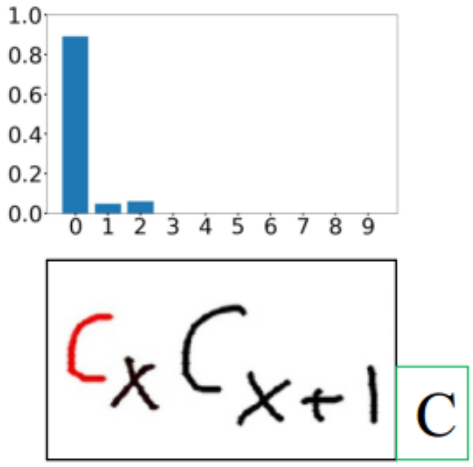
a x ^ { 2 } + b =

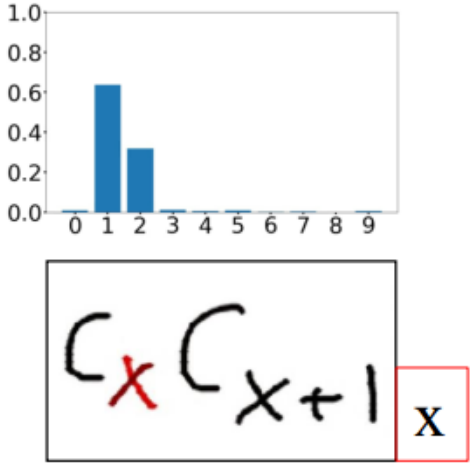
# Introduction

## OHMER Challenges

- Symbol segmentation
- 2D Structural analysis



# Proposed methods

**Two ways to improve the previous model (TAP)**

① Posterior attention mechanism

② Stroke level features

Posterior attention is better to be implemented on stroke-level features than point-level features as the output probabilities generated by stroke is more convincing than generated by point.

# Proposed methods

Two ways to alleviate this problem:

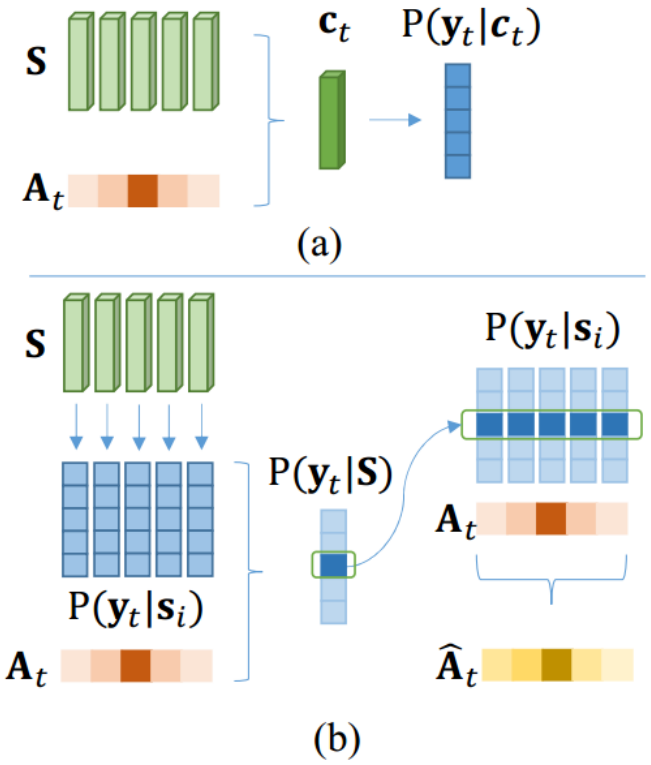
① Posterior attention mechanism

② Stroke level features

Simplified flowchart:

(a) Soft attention

(b) Posterior attention

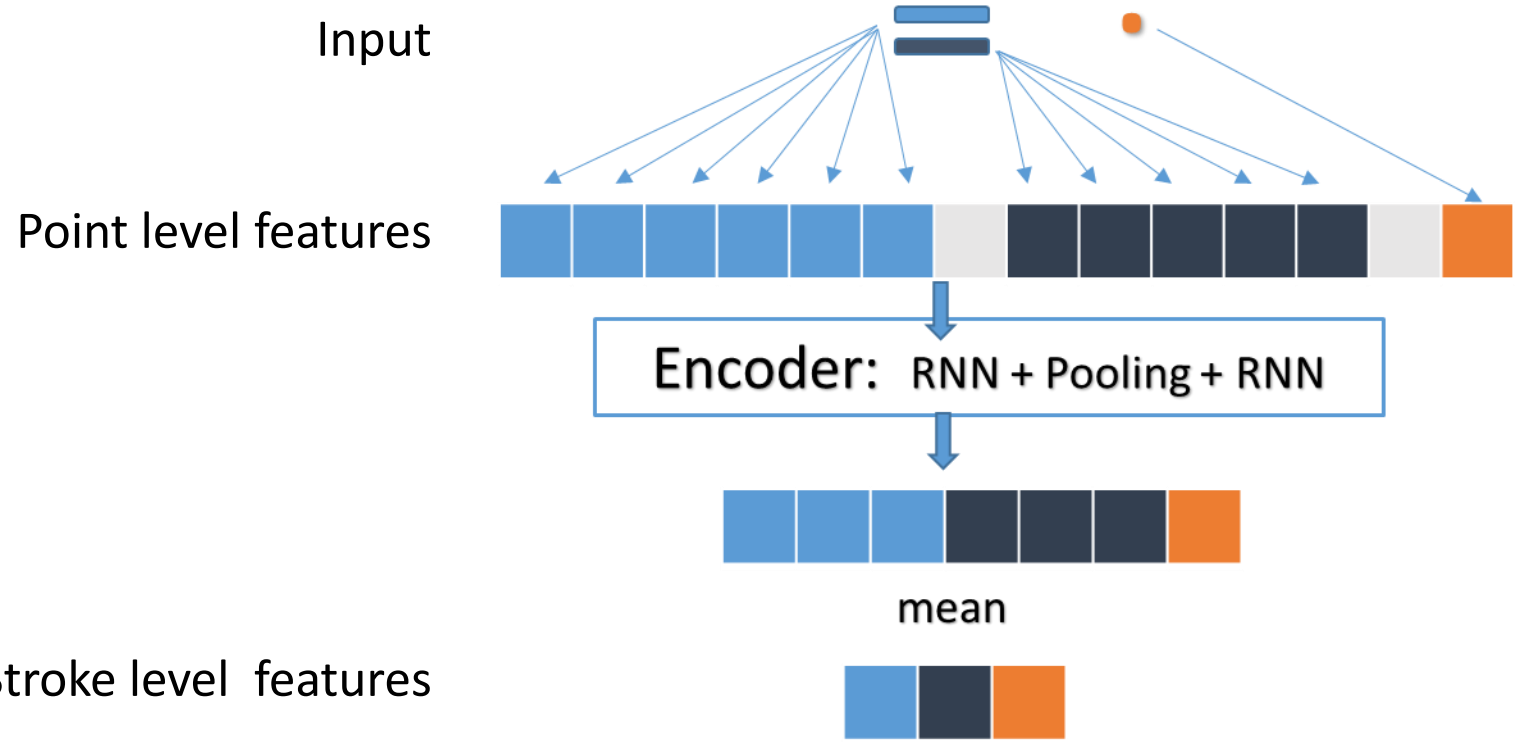


# Proposed methods

Two ways to alleviate this problem:

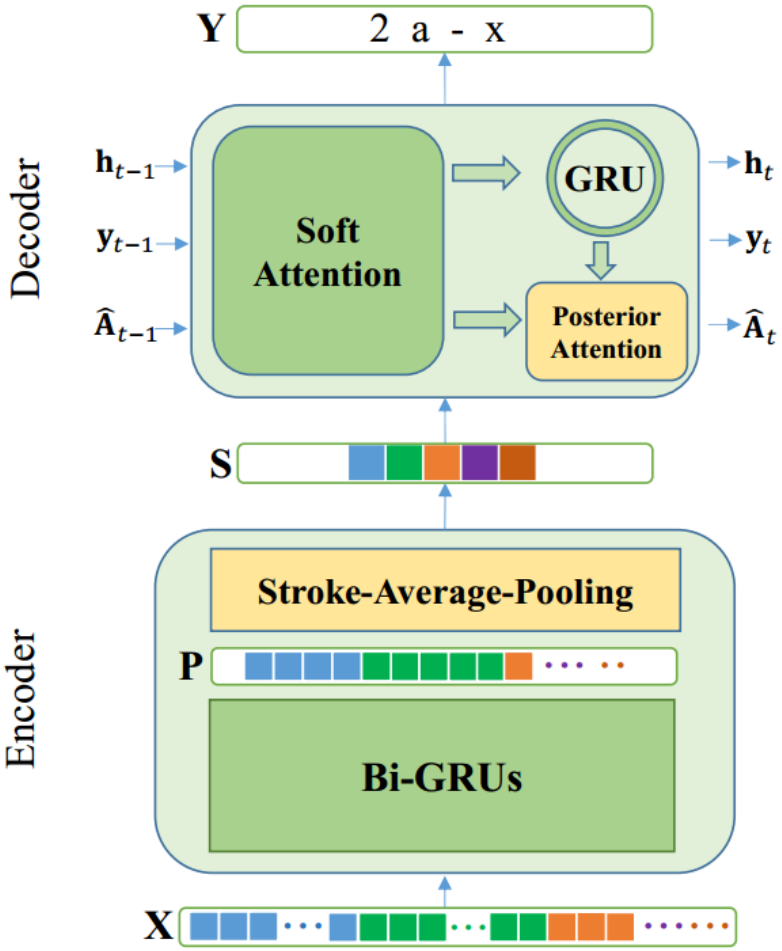
① Posterior attention mechanism

② Stroke level features



# Proposed methods: overall architecture

## Network Architecture



# Experiments

## Evaluation of Posterior Attention Mechanism

TABLE I
COMPARISON OF RECOGNITION PERFORMANCE (IN %) ON CROHME 2014 AND CROHME 2016 BETWEEN SYSTEM I TO IV

| System | Attention | Feature Level | CROHME 2014 | | CROHME 2016 | |
|---|---|---|---|---|---|---|
| | | | WER | ExpRate | WER | ExpRate |
| I | soft | point | 13.34 | 50.71 | 14.67 | 45.95 |
| II | posterior | point | 11.97 | 51.28 | 13.21 | 47.28 |
| III | soft | stroke | 13.29 | 50.91 | 14.53 | 47.60 |
| IV | posterior | stroke | 10.44 | 54.26 | 12.68 | 51.75 |

# Experiments

## Attention visualization

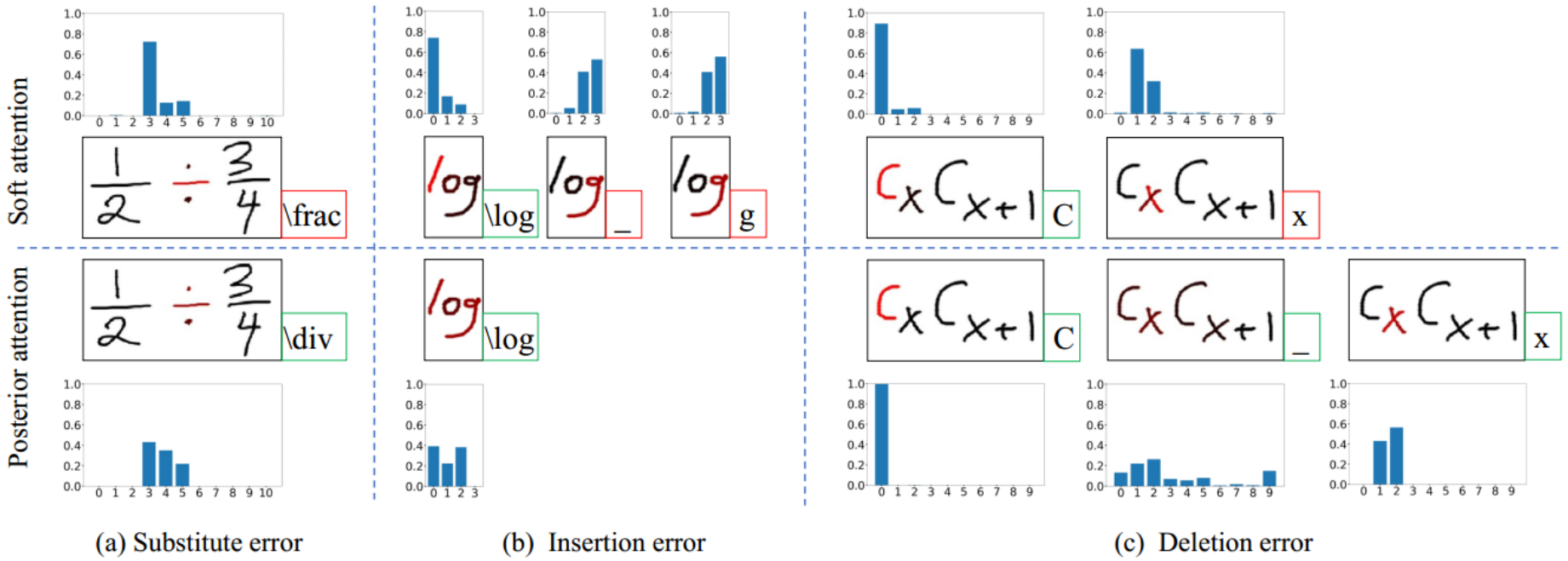



Fig. 3. Three examples of attention visualization with soft attention and posterior attention. The horizontal axis of the histogram represents the serial number of the strokes, and the vertical axis represents the value of the attention weight.

# Experiments:

## Comparison with State-of-the-arts

TABLE III
COMPARISON OF EXPRATE (IN %) ON CROHME 2014 AND CROHME 2016

| System | CROHME 2014 | | | | CROHME 2016 | | | |
|---|---|---|---|---|---|---|---|---|
| | ExpRate | ≤1 | ≤2 | ≤3 | ExpRate | ≤1 | ≤2 | ≤3 |
| Wiris [10] | - | - | - | - | 49.61 | 60.42 | 64.69 | - |
| Tokyo [10] | - | - | - | - | 43.94 | 50.91 | 53.70 | - |
| Merge 9 [26] | 29.91 | 39.94 | 44.96 | 50.15 | 27.03 | 35.48 | 42.46 | - |
| PGS [27] | 48.78 | 66.13 | **73.94** | **79.01** | 45.60 | 62.25 | **70.44** | **75.76** |
| TAP | 50.71 | 65.42 | 68.73 | 69.54 | 45.95 | 60.77 | 63.85 | 64.57 |
| Res-BiRNN [28] | 53.35 | 64.50 | 70.08 | 72.92 | 47.95 | 60.16 | 65.56 | 68.61 |
| Ours | **54.26** | **69.64** | 72.65 | 73.26 | **51.75** | **65.18** | 68.27 | 68.99 |

# Conclusion

① The posterior attention mechanism is better than soft attention mechanism

② The stroke-level feature vectors which contain enough classification information can calculate posterior attention accurately

③ The proposed stroke based posterior attention exhibits higher performance than previous methods.

# Thanks for listening