

On-line recognition of handwritten mathematical symbols

Bachelor's thesis of Martin Thoma

Martin Thoma | 5th of June, 2014

$$1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{\dots}}}$$

$$\frac{1 + \sqrt{5}}{2}$$

- 1 What is my Bachelor's thesis about?
- 2 write-math.com
- 3 Preprocessing and Features
- 4 Neural Nets
- 5 What will I do next?

What is my Bachelor's thesis about?

- Recognition of handwritten mathematical symbols
- On-line recognition, not OCR!
- Given a series of points $(x(t), y(t), b(t))$
I want to get the proper \LaTeX code.

Why do I work on this topic?

- \LaTeX is easy as soon as you know the \backslash codes.
- It's hard to find the \LaTeX code of single symbols.
- It's much harder to find complete formulas.

For now: recognition of isolated symbols. That means:
single symbol “formulae” rather than multi symbol formulae

- a website where users can add labeled training data and unlabeled data which they want to classify. I call this data “recording”

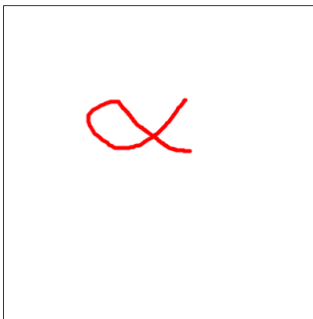


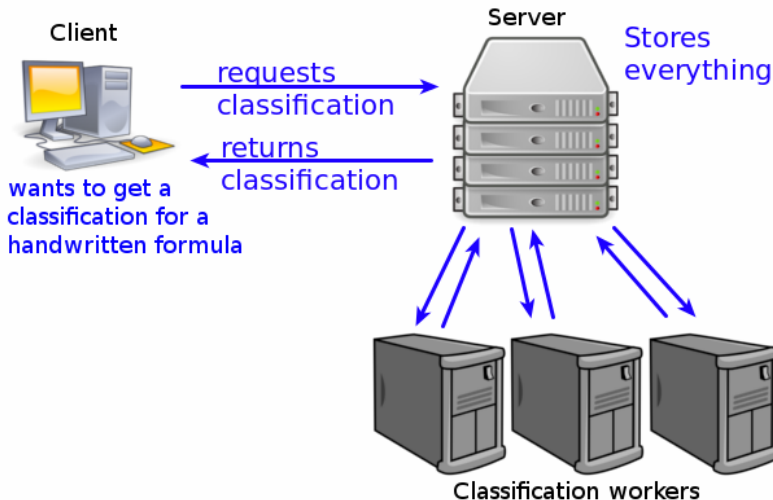
4 recordings

- works with desktop computers and touch devices
- symbol recognition can be done by multiple classifiers
- users can contribute formulas as recordings and as \LaTeX answers for recordings
- users can vote for \LaTeX answers: \leq , \leqslant , \lesssim , ...
- user who entered the recording can accept one answer

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Ranking

Only users with at least 5 written formulas will be listed below.

#	User	Written formulas	Distinct symbols
1	Detexify	217684	1125
2	Martin Thoma	4382	523
3	user_639125948	3071	430
4	Eva	1134	566
5	John	781	722
6	TorbjornT	572	253
7	user_1904016610	510	124
8	Marienkaefer	458	260
9	percusse	411	317
10	Brent	374	196

- 127 users with at least 5 recordings
- 1111 symbols, but only 369 used for experiments
- 235 831 recordings (e.g. 3489 times `\int`, but only 50 times `X`)

- preprocessing: Scale to fit into unit square while keeping the aspect ratio
 - applies greedy time warping
 - compares a new recording with every recording in the database
- ⇒ Classification time is in $\mathcal{O}(\text{recordings})$, but we rather would like $\mathcal{O}(\text{symbols})$
- the current server / workflow can only handle about 4000 recordings
- ⇒ Another way to classify is necessary

- Normalizing
 - Scaling
 - Shifting
 - Resampling
- Noise reduction
 - Smoothing (e.g. moving average)
 - Dot reduction
 - Filtering (by distance, speed or angle)
 - Stroke connection

- Local
 - Coordinates
 - Speed
 - Binary pen pressure
 - Direction
 - Curvature
 - Bitmap-environment
 - Hat-Feature
- Global
 - # of points
 - # of strokes
 - Center point
 - Bitmap
 - Bounding box (width, height, time)

Preprocessing: Scaling, shifting and linear interpolation

Features: Coordinates of 80 points (4 strokes with 20 points each)

Learning: MLP, 300 epochs, LR of 0.1, Momentum 0.1

Topology	Error	Training time
160:500:369	30.62 %	9min 08s
160:500:500:369	27.73 %	11min 49s
160:500:500:500:369	34.79 %	14min 09s
160:500:500:500:500:369	33.61 %	14min 06s

Examples of confusable symbols

\LaTeX	Rendered	\LaTeX	Rendered
$\backslash\text{sum}$	Σ	$\$\backslash\text{Sigma}\$$	Σ
$\backslash\text{coprod}$	\amalg	$\$\backslash\text{amalg}\$$	\amalg
$\backslash\text{perp}$	\perp	$\$\backslash\text{bot}\$$	\perp
$\backslash\text{models}$	\models	$\$\backslash\text{vDash}\$$	\models
$\backslash\text{emptyset}$	\emptyset	$\$\backslash\text{diameter}\$$	\varnothing
		$\$\backslash\text{o}\$$	\varnothing
		$\$\backslash\text{varnothing}\$$	\varnothing
$\backslash\text{Delta}$	Δ	$\$\backslash\text{triangle}\$$	\triangle
$\backslash\text{varepsilon}$	ε	$\$\backslash\text{mathcal}\{\text{E}\}\$$	\mathcal{E}

When those confusions are not counted as errors, the current best system has an classification error rate of 12.7% (otherwise 22.2%).

What will I do next?

- Include the currently best model in write-math.com
- Evaluate preprocessing steps
- Try other features
- Try other topologies / trainings (e.g. pretraining, newbob)
- Eventually try convolutional neural nets

- [Server](#) by RRZEicons
- [Desktop Computer](#) by Ed g2s, Ironbrother, Kierancassel and Msgj
- [Server](#) by MimooH

Thanks for Your Attention!



2014-05-24 14:59:56



2014-05-23 10:18:10



2014-05-22 19:12:11



2014-05-22 19:07:06



2014-05-22 16:31:59



2014-05-22 12:36:09



2014-05-22 11:31:21



2014-05-22 11:23:53



2014-05-12 21:40:15



2014-05-09 18:02:01