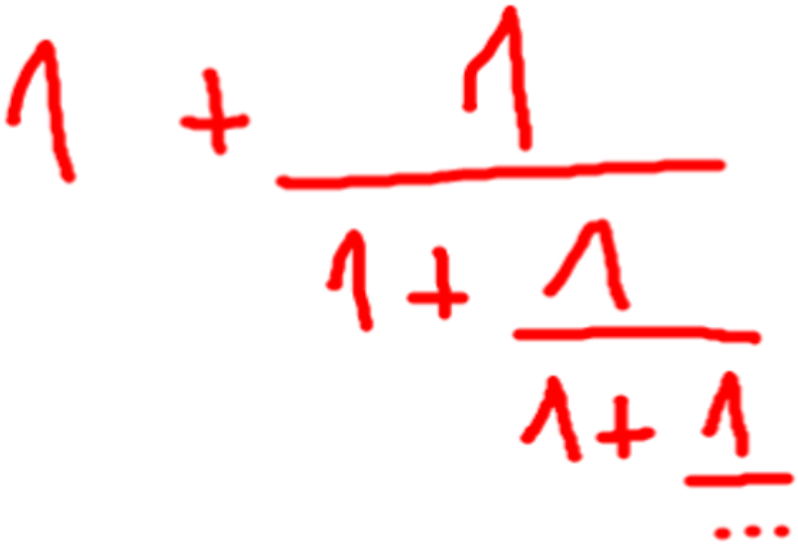
Karlsruhe Institute of Technology

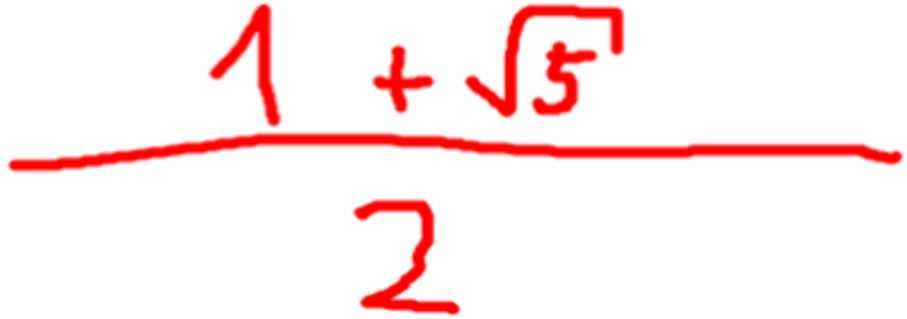
Carnegie Mellon University

On-line recognition of handwritten mathematical symbols

Bachelor's thesis of Martin Thoma

Martin Thoma | 5th of June, 2014





Contents

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 \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

write-math.com

- 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: $\leq$, $\leqq$, $\leqslant$, ...
- user who entered the recording can accept one answer

Classify


Write Math
Classify
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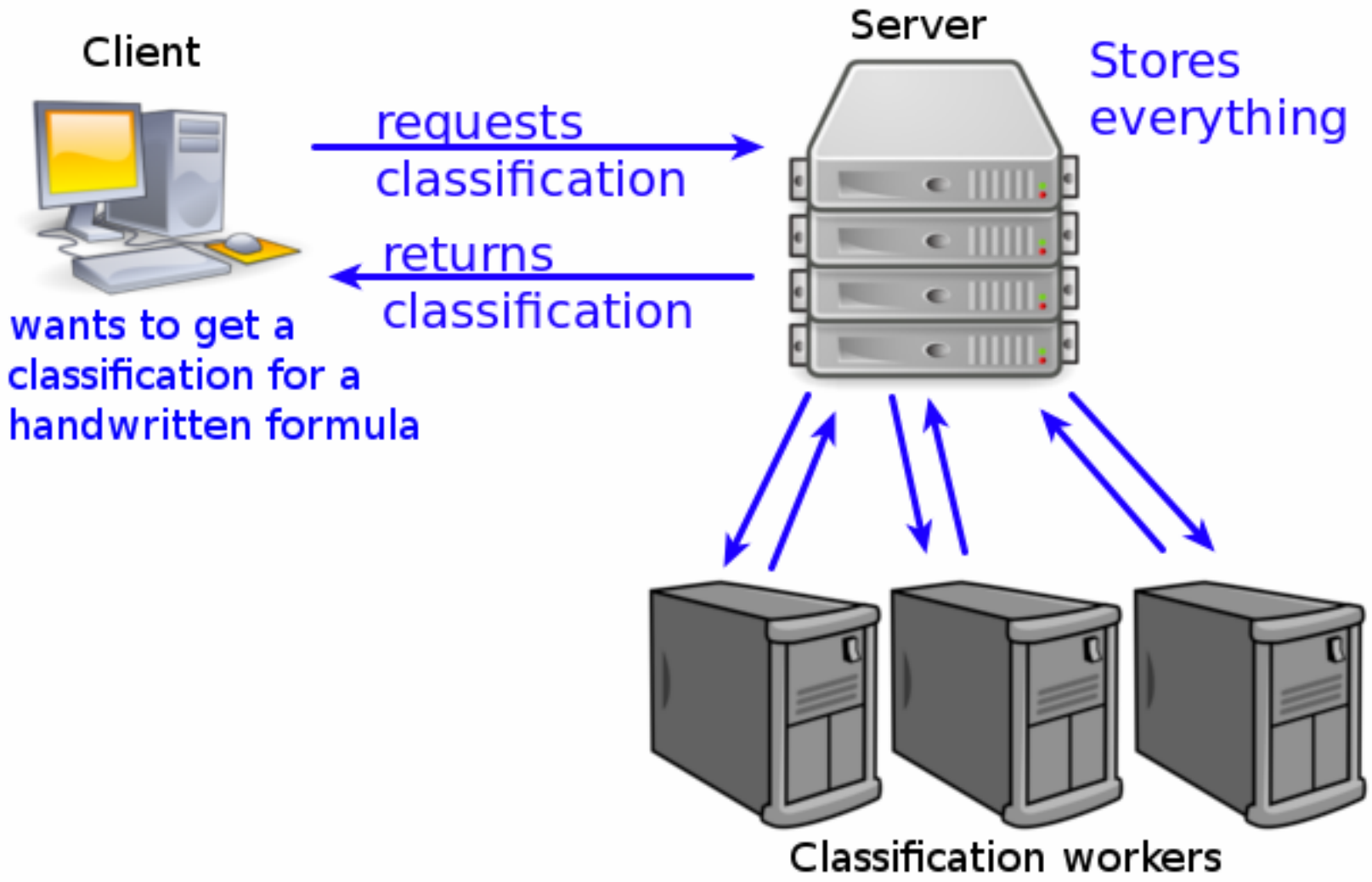
Workflow


Client
Server
Stores everything
requests classification
returns classification
wants to get a classification for a handwritten formula
Classification workers

Ranking

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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

Statistics

- 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`)

First classification worker

- 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

$\Rightarrow$ 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

$\Rightarrow$ Another way to classify is necessary

Preprocessing

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

Features

- 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)

Experiments

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

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

Image Sources

- Server by RRZEicons
- Desktop Computer by Ed g2s, Ironbrother, Kierancassel and Msgj
- Server by Mimooh

The presentation can be found at
http://tinyurl.com/write-math-short-presentation

Thanks for Your Attention!