On-line recognition of handwritten mathematical symbols

Bachelor's thesis of Martin Thoma

Martin Thoma | 5th of June, 2014

$$1 + \cfrac{1}{1 + \cfrac{1}{1 + \cfrac{1}{\cdots}}} \qquad \frac{1 + \sqrt{5}}{2}$$

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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.

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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

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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"
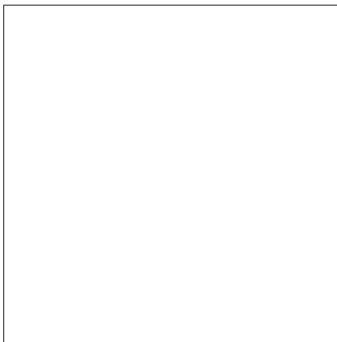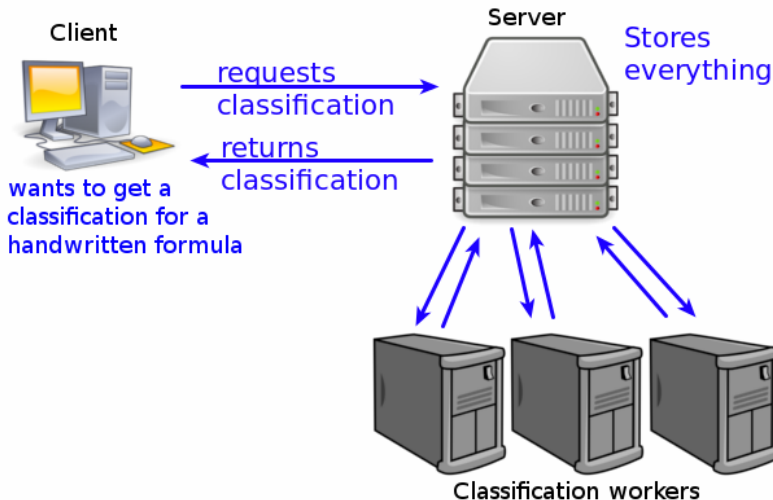

4 recordings

- 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 wrote the formula can accept one answer

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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

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Ranking

Statistics

- 127 users with at least 5 recordings
- 1109 symbols, but only 369 used for experiments
- 235 831 recordings (e.g. 3486 times \int)

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OO   OOOO●OO   OO   OO   O   OO
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First classification worker

- preprocessing: Scale to fit into unit square while keeping the aspect ratio
- applies dynamic 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

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Preprocessing

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

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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)

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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

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

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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	$\emptyset$	$\diameter$	$\varnothing$
		$\o$	$\varnothing$
		$\varnothing$	$\varnothing$
\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%).

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What will I do next?

- Evaluate preprocessing steps
- Try other features
- Try other topologies / trainings (e.g. pretraining, newbob)

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Image Sources

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

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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

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