

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 Preprocessing and Features

3 Evaluation

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 \LaTeX command.

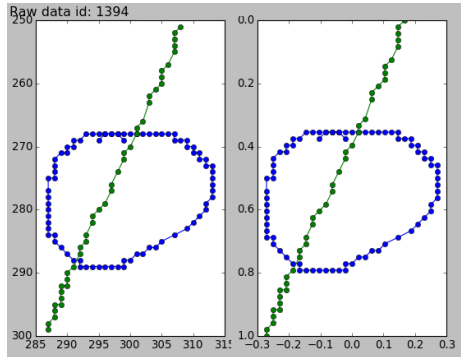
Why did I work on this topic?

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

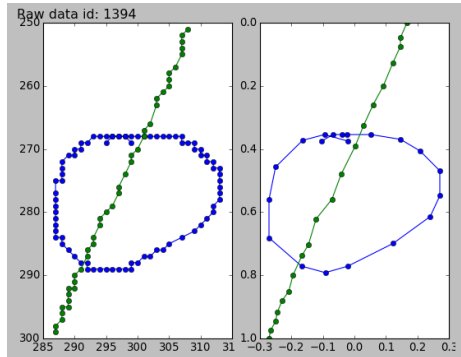
For now: recognition of isolated symbols.

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

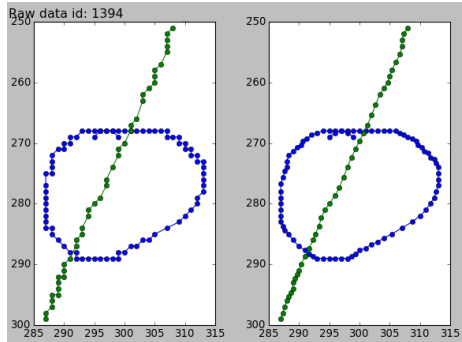
- Normalizing
 - Scaling
 - Shifting
 - Resampling
- Noise reduction
 - Smoothing (e.g. moving average)
 - Dot reduction
 - Filtering (by distance, speed or angle)
 - Stroke connection



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



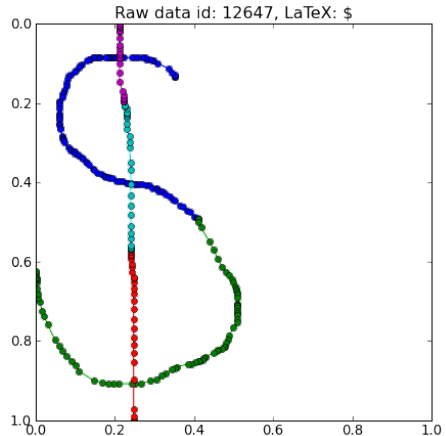
- Normalizing
 - Scaling
 - Shifting
 - Resampling
- Noise reduction
 - Smoothing (e.g. moving average)
 - Dot reduction
 - Filtering (by distance, speed or angle)
 - Stroke connection



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

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

- 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)
- Re-curvature
- Ink

Merged symbols (MER error)

Base symbol		equivalent symbols	
L ^A T _E X	Rendered	L ^A T _E X	Rendered
<code>\sum</code>	Σ	<code>\$_Sigma\$</code>	Σ
<code>\prod</code>	Π	<code>\$_Pi\$</code>	Π
		<code>\$_sqcap\$</code>	\sqcap
<code>\coprod</code>	\coprod	<code>\$_amalg\$</code>	\amalg
		<code>\$_sqcup\$</code>	\sqcup
<code>\perp</code>	\perp	<code>\$_bot\$</code>	\bot
<code>\models</code>	\models	<code>\$_vDash\$</code>	\models
<code> </code>	$ $	<code>\mid</code>	\mid
<code>\Delta</code>	Δ	<code>\$_triangle\$</code>	\triangle
		<code>\$_vartriangle\$</code>	\vartriangle

Merged symbols (MER error)

Base symbol		equivalent symbols	
L ^A T _E X	Rendered	L ^A T _E X	Rendered
<code>\ </code>		<code> \$\parallel\$ </code>	
<code>\ohm</code>	Ω	<code> \$\Omega\$ </code>	Ω
<code>\setminus</code>	\	<code> \$\backslash\$ </code>	\
<code>\checked</code>	✓	<code> \$\checkmark\$ </code>	✓
<code>\&</code>	&	<code> \$\with\$ </code>	&
<code>\#</code>	#	<code> \$\sharp\$ </code>	#
<code>\S</code>	§	<code> \$\mathsection\$ </code>	§
<code>\nabla</code>	▽	<code> \triangledown </code>	▽
<code>\lhd</code>	◁	<code> \$\triangleleft\$ </code>	◁
		<code> \$\vartriangleleft\$ </code>	◁
<code>\oiint</code>	∬	<code> \$\varoiint\$ </code>	∬

Merged symbols (MER error)

Base symbol		equivalent symbols	
\LaTeX	Rendered	\LaTeX	Rendered
$\text{\textbackslash mathbb{R}}$	\mathbb{R}	$\text{\$}\text{\textbackslash mathds{R}}\text{\$}$	\mathbb{R}
$\text{\textbackslash mathbb{Q}}$	\mathbb{Q}	$\text{\textbackslash mathds{Q}}$	\mathbb{Q}
$\text{\textbackslash mathbb{Z}}$	\mathbb{Z}	$\text{\textbackslash mathds{Z}}$	\mathbb{Z}
$\text{\textbackslash mathcal{A}}$	\mathcal{A}	$\text{\textbackslash mathscr{A}}$	\mathcal{A}
$\text{\textbackslash mathcal{D}}$	\mathcal{D}	$\text{\textbackslash mathscr{D}}$	\mathcal{D}
$\text{\textbackslash mathcal{N}}$	\mathcal{N}	$\text{\textbackslash mathscr{N}}$	\mathcal{N}
$\text{\textbackslash mathcal{R}}$	\mathcal{R}	$\text{\textbackslash mathscr{R}}$	\mathcal{R}
$\text{\textbackslash propto}$	\propto	$\text{\$}\text{\textbackslash varpropto}\text{\$}$	\propto

Preprocessing: Scaling, shifting and linear interpolation

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

Learning: MLP, 1000 epochs, LR $\eta = 0.1$, Momentum $\alpha = 0.1$

System	Topology	Classification error		
		TOP1	TOP3	MER
B_1	160:500:369	23.34 %	6.80 %	6.64 %
B_2	160:500:500:369	<u>21.51 %</u>	5.75 %	5.67 %
B_3	160:500:500:500:369	21.93 %	<u>5.74 %</u>	<u>5.64 %</u>
B_4	160:500:500:500:500:369	23.88 %	6.12 %	6.04 %

Table: Baseline systems with three different classification error measures. All errors were measured on the test set.

Complex classifier

Preprocessing: Connect strokes, scale, shift and linear interpolation

Features: Coordinates of 80 points (4 strokes with 20 points each), re-curvature per stroke, ink, stroke count, aspect ratio

Learning: MLP, 1000 epochs, LR $\eta = 0.1$, Momentum $\alpha = 0.1$, supervised layer-wise pretraining

System	Classification error					
	TOP1	change	TOP3	change	MER	change
$B_{1,c}$	20.96 %	-2.38 %	5.24 %	-1.56 %	5.13 %	-1.51 %
$B_{2,c}$	18.26 %	-3.25 %	4.07 %	-1.68 %	<u>3.98 %</u>	-1.69 %
$B_{3,c}$	<u>18.19 %</u>	-3.74 %	<u>4.06 %</u>	-1.68 %	3.99 %	-1.65 %
$B_{4,c}$	18.57 %	-5.31 %	4.25 %	-1.87 %	4.18 %	-1.86 %

Table: Error rates of the complex recognizer systems.

Two software projects were created:

- write-math.com: A website where on-line handwritten data gets collected and classified
- [hwrt](#): The *handwriting recognition toolkit* is a Python project for handwriting recognition

This presentation and the bachelor's thesis will be at martin-thoma.com/write-math.

- [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