Measuring Similarity of Educational Items Using Data on Learners' Performance

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Adaptive Learning
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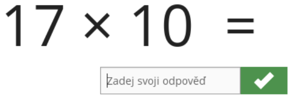
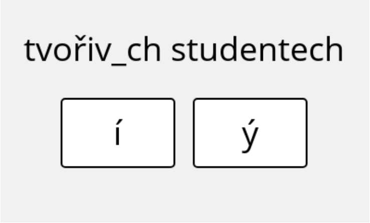
Adaptive learning

Adaptive practice systems

- **items** — simple questions
- practice — rapid sequence of items





Motivation

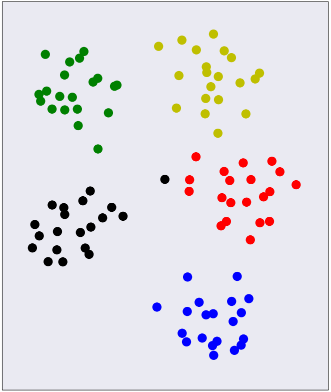
Large pool of items

- How to organize these items?
- What knowledge components should be use?
- Are there some anomalies?
- ...

Motivation

Large pool of items

- **clustering**
- visualization
- outlier detection
- ...



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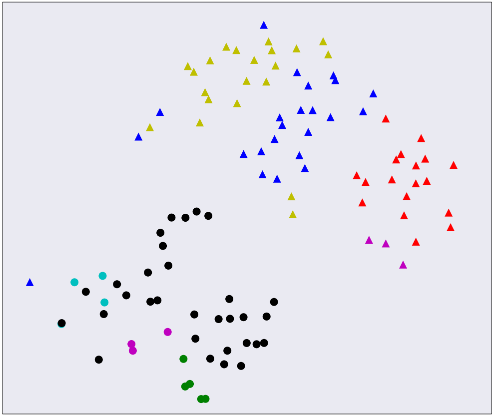
Motivation

Large pool of items

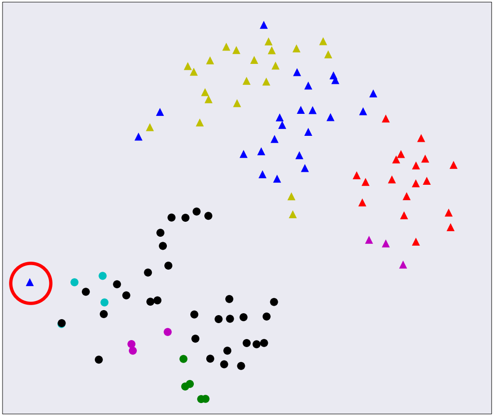
- clustering
- **visualization**
- outlier detection
- ...



Motivation

Large pool of items

- clustering
- visualization
- **outlier detection**
- . . .



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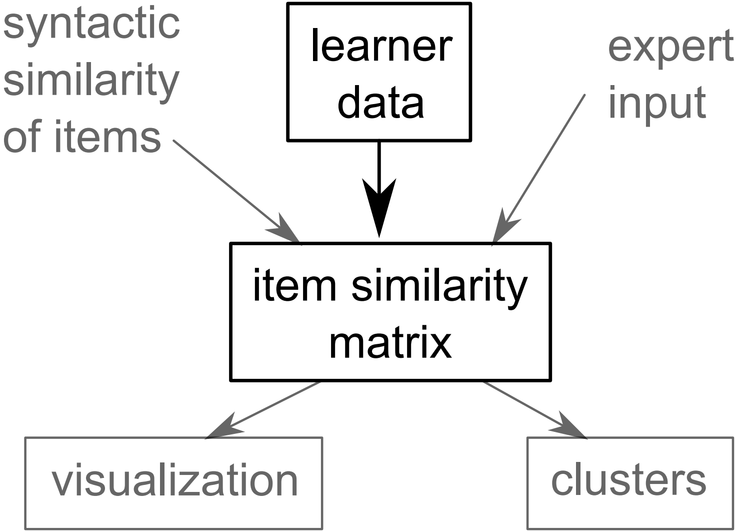
General approach



Similarity measures

matrix of answers

	i_1	$\cdots$	i_m	$\cdots$	i_n	$\cdots$	i_I
l_1	1		1		1		0
l_2	-		1		0		-
l_3	1		0		-		0
$\vdots$	$\vdots$		$\vdots$		$\vdots$		$\vdots$
l_L	0		-		1		-

similarity measure

similarity matrix

	$\cdots$	i_m	$\cdots$	i_n	$\cdots$
$\vdots$					
i_m		1		0.63	
$\vdots$					
i_n		0.63		1	
$\vdots$					

Similarity measures

binary data

- 1 — correct
- 0 — incorrect
- input can be simplified:

		item i	
		incorrect	correct
item j	incorrect	a	b
	correct	c	d

Similarity measures

Yule	$S_y = (ad - bc)/(ad + bc)$
Pearson	$S_p = (ad - bc)/\sqrt{(a+b)(a+c)(b+d)(c+d)}$
Cohen	$S_c = (P_o - P_e)/(1 - P_e)$ $P_o = (a+d)/n$ $P_e = ((a+b)(a+c) + (b+d)(c+d))/n^2$
Sokal	$S_s = (a+d)/(a+b+c+d)$
Jaccard	$S_j = a/(a+b+c)$
Ochiai	$S_o = a/\sqrt{(a+b)(a+c)}$

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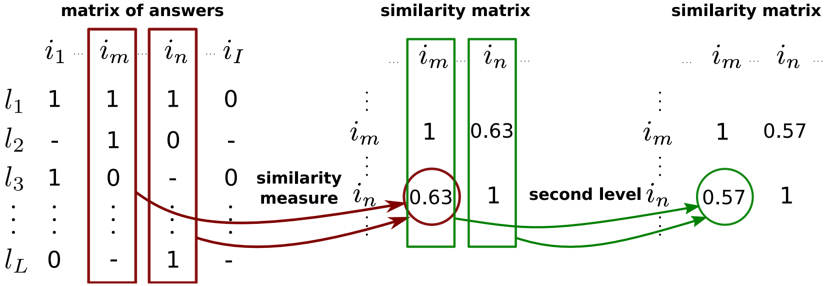
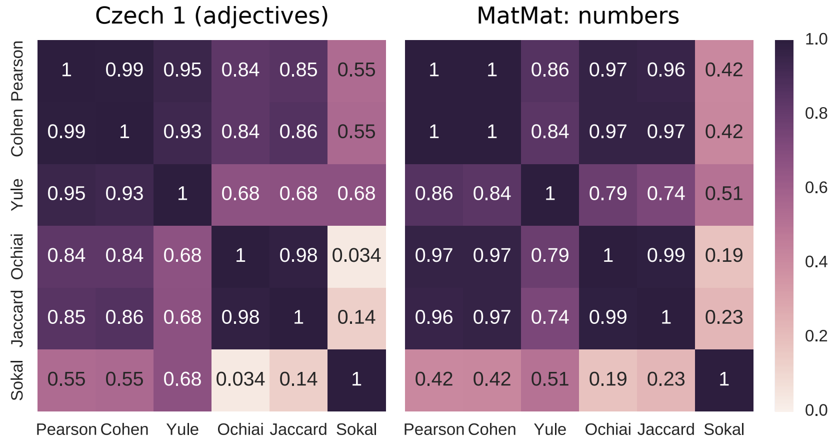
Second level of similarity



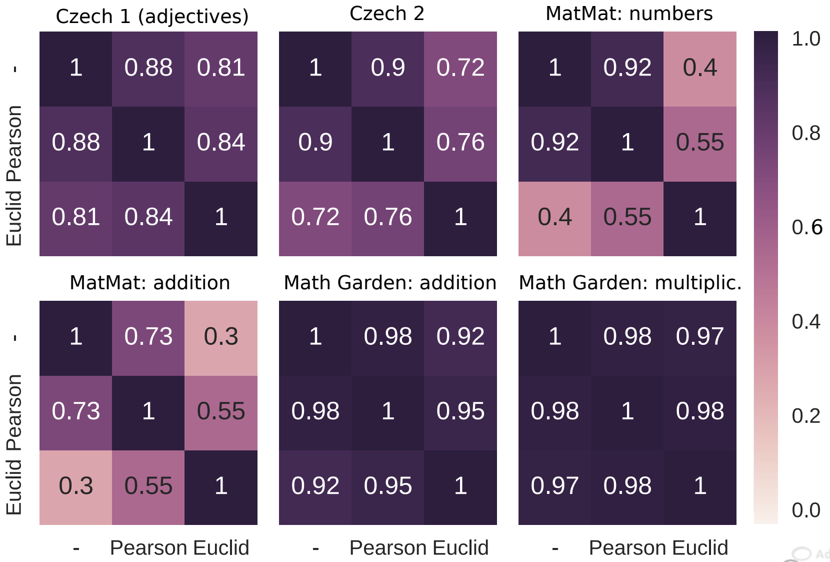
Second level of similarity

- 2 items are similar if they are *similarly* similar to other items
- more information used
- noise reduction
- necessary for some follow up algorithms

Evaluation - correlation of measures



Evaluation - correlation of measures



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Simulated data

Simulated data

- we know *right answer*
- logistic model
  - learners have skills
  - items have difficulty
- typical setting
  - 100 learners
  - 5 knowledge components
  - 20 items per KC

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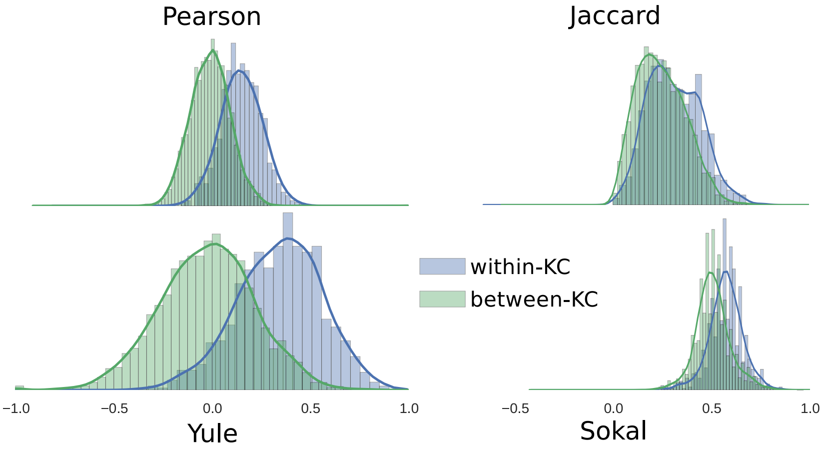
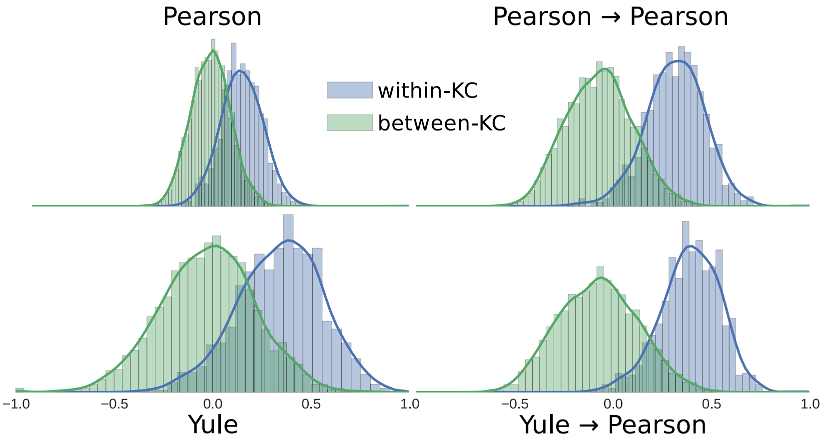
Evaluation

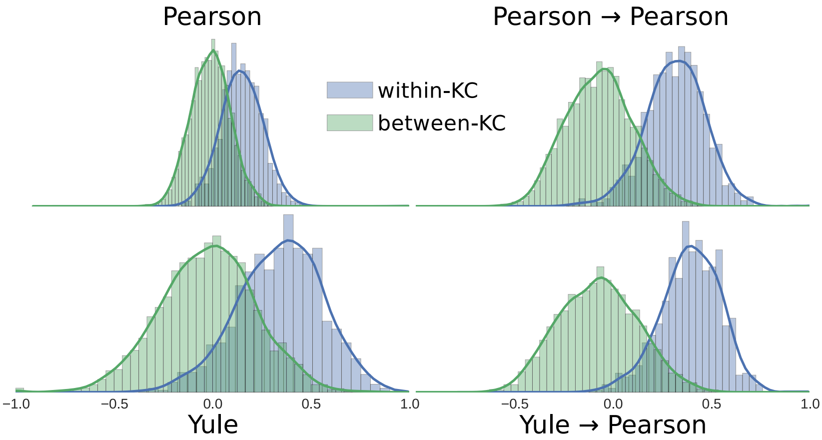


Pearson
Jaccard
within-KC
between-KC
−1.0
−0.5
0.0
0.5
1.0
Yule
−0.5
0.0
0.5
1.0
Sokal

Evaluation


Pearson
Pearson → Pearson
within-KC
between-KC
−1.0
−0.5
0.0
0.5
1.0
−0.5
0.0
0.5
1.0
Yule
Yule → Pearson

Evaluation



Pearson
Pearson → Pearson
within-KC
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−0.5
0.0
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1.0
−0.5
0.0
0.5
1.0
Yule
Yule → Pearson

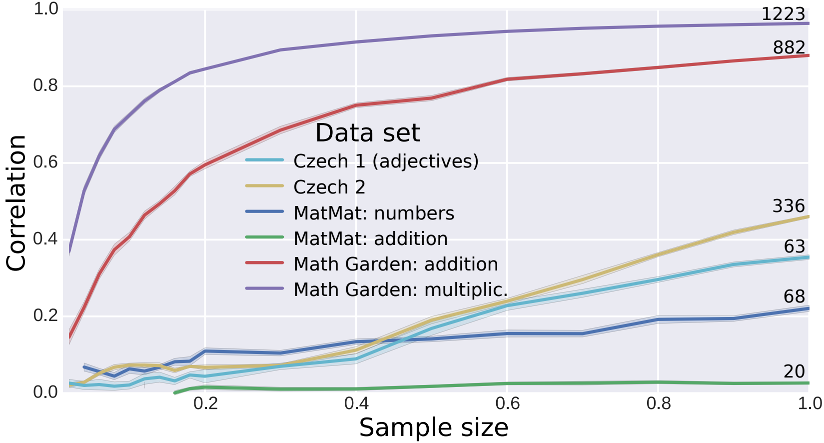
Evaluation - clustering

	Czech adjectives	100L 5KC	200L 5KC
Pearson	0.32 ± 0.02	0.48 ± 0.05	0.84 ± 0.05
Jaccard	0.31 ± 0.03	0.15 ± 0.04	0.29 ± 0.08
Yule	0.31 ± 0.03	0.43 ± 0.05	0.77 ± 0.07
Sokal	0.15 ± 0.06	0.18 ± 0.03	0.25 ± 0.05
Pearson $\rightarrow$ Euclid	$\mathbf{0.43} \pm 0.01$	$\mathbf{0.80} \pm 0.06$	$\mathbf{0.98} \pm 0.01$
Yule $\rightarrow$ Euclid	0.32 ± 0.02	0.65 ± 0.07	0.94 ± 0.04
Pearson $\rightarrow$ Pearson	0.41 ± 0.03	0.73 ± 0.06	0.96 ± 0.02
Yule $\rightarrow$ Pearson	0.32 ± 0.03	0.72 ± 0.06	0.97 ± 0.02

Do We Have Enough Data?

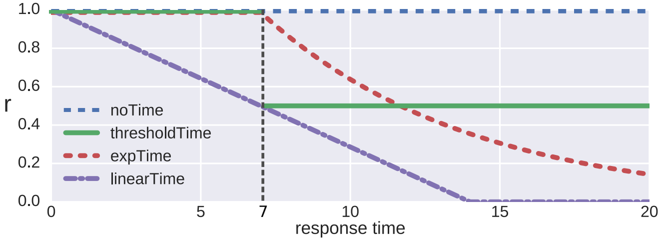
- stability of results
- split data to two halves
- how similarity measures correlate on these halves?

Do We Have Enough Data?

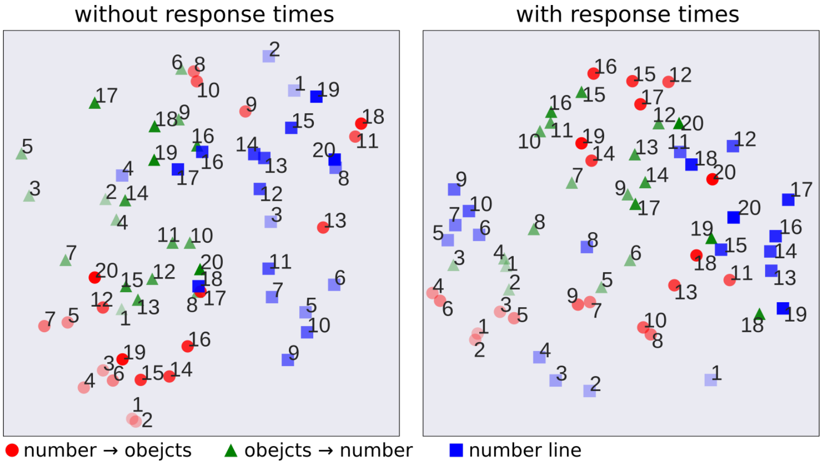


Response times

- additional information
- correctness and response time to one measure of success



Respose times - MathMat



Respose times - Math Garden

- Math Garden - large datasets: $\sim 1M$ of answer on 30 items
- small impact of time information - correlation > 0.9
- but what we have not such large dataset

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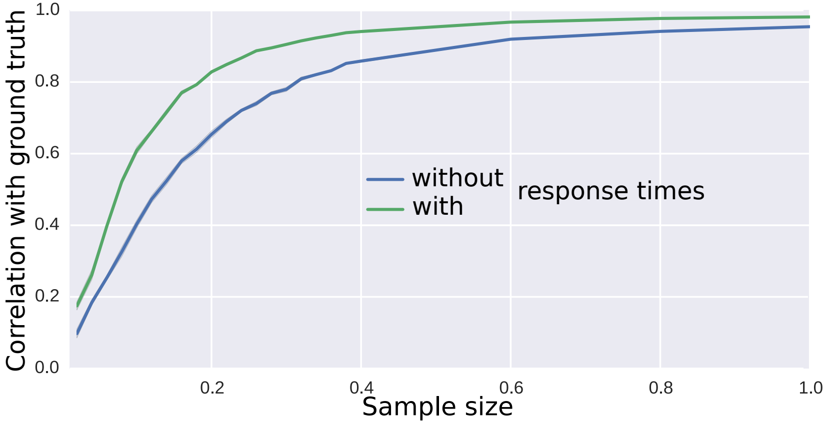
Respose times - MathGarden



Conclusion

- Pearson (Cohen) and Yule are better
- second level improve results
- we should check that we have sufficient data
- response time can give different point of view
- response time can help with small datasets