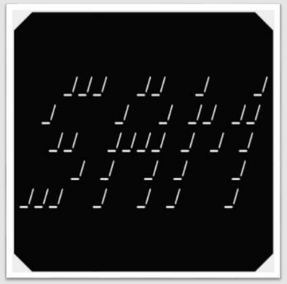
LineUp

Visual Analysis of Multi-Attribute Rankings

CALEYDO

JKU
JOHANNES KEPLER
UNIVERSITY LINZ

HARVARD
UNIVERSITY


Samuel Gratzl


Marc Streit


Alexander Lex


Nils Gehlenborg


Hanspeter Pfister

Rankings are omnipresent

Goal

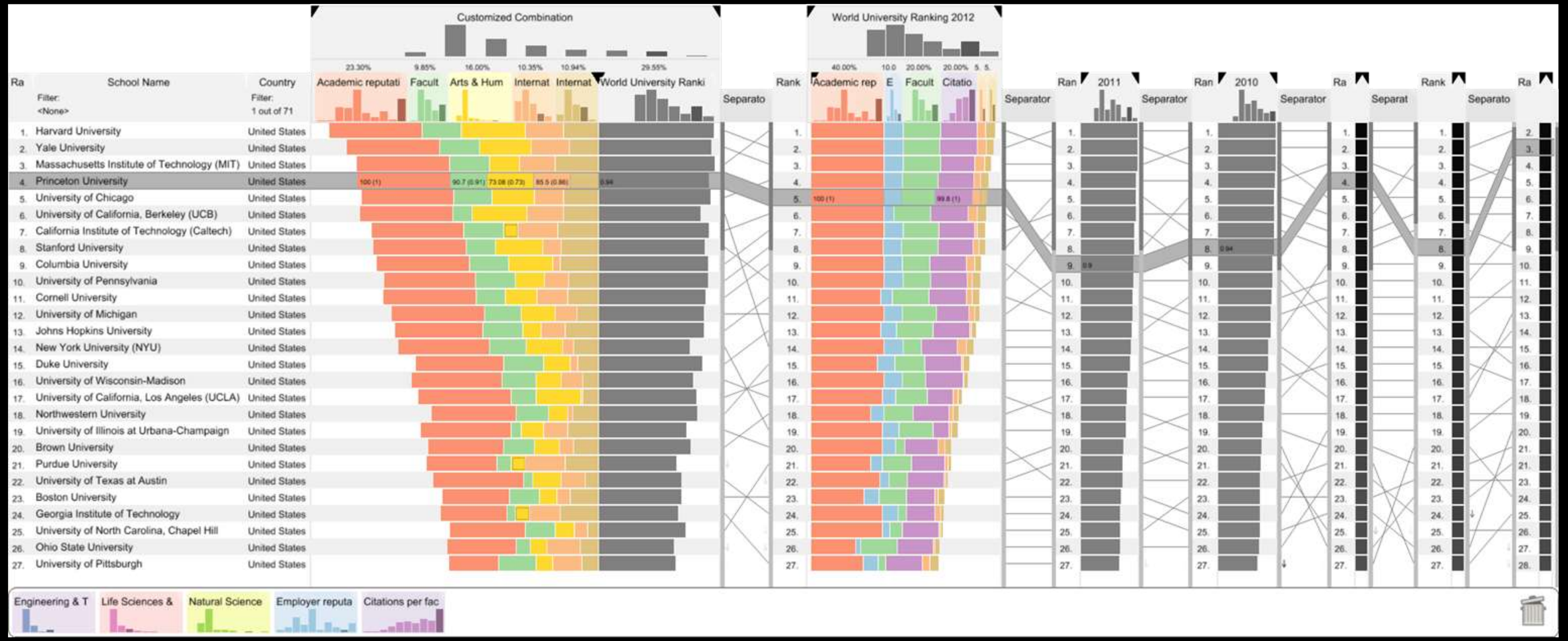
Intuitive
Interactive
Multi-Attribute
Ranking Visualization

Goal

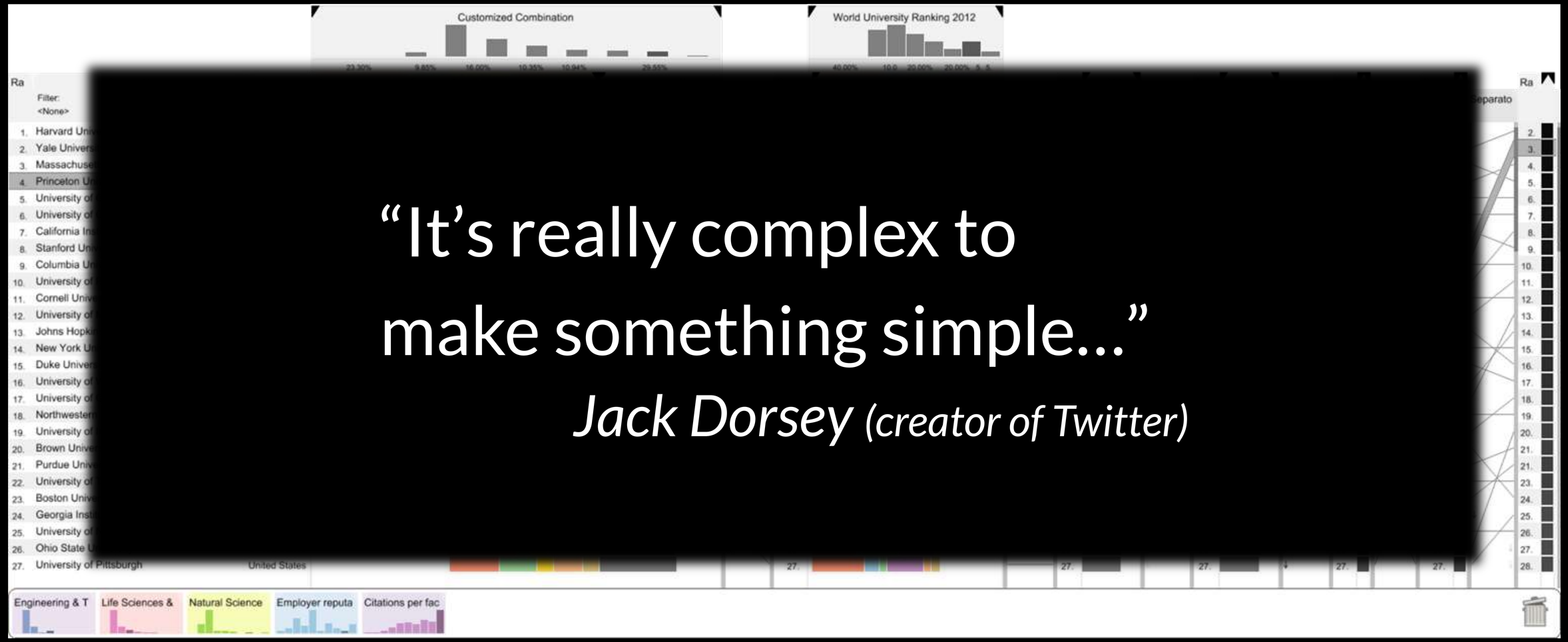
Intuitive
Interactive
Multi-Attribute
Ranking Visualization
To Create
Refine
Explore

10 Requirements

LineUp

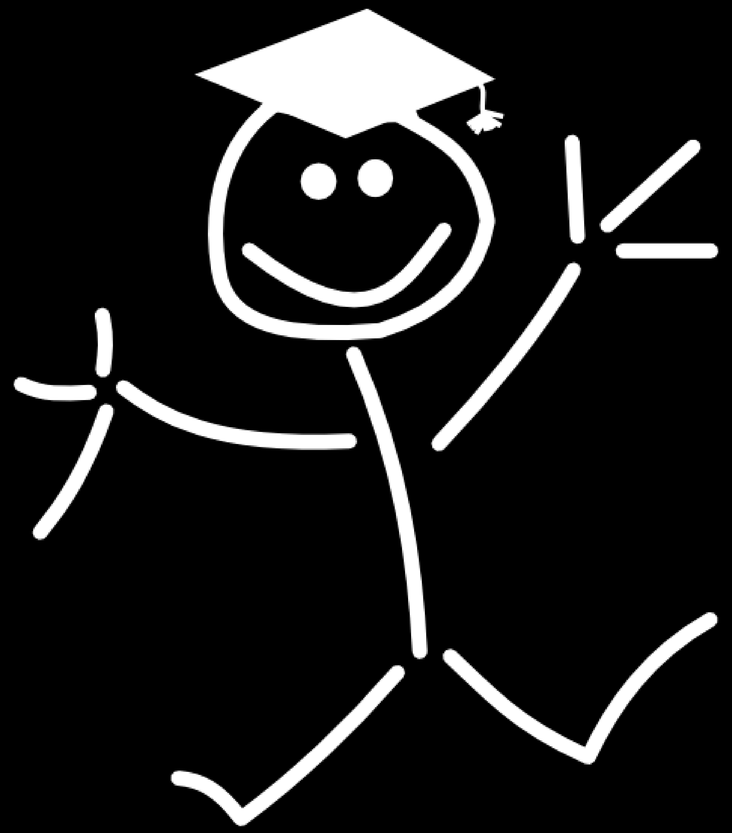

Customized Combination
World University Ranking 2012
Ra
School Name
Filter:
<None>
Country
Filter:
1 out of 71
23.30%
9.85%
16.00%
10.35%
10.94%
29.55%
Academic reputati
Facult
Arts & Hum
Internat
Internat
World University Ranki
Separato
Rank
40.00%
10.0
20.00%
20.00%
5.
5.
Academic rep
E
Facult
Citatio
Separator
Ran
2011
2010
Ra
Separat
Rank
1. Harvard University United States
2. Yale University United States
3. Massachusetts Institute of Technology (MIT) United States
4. Princeton University United States
5. University of Chicago United States
6. University of California, Berkeley (UCB) United States
7. California Institute of Technology (Caltech) United States
8. Stanford University United States
9. Columbia University United States
10. University of Pennsylvania United States
11. Cornell University United States
12. University of Michigan United States
13. Johns Hopkins University United States
14. New York University (NYU) United States
15. Duke University United States
16. University of Wisconsin-Madison United States
17. University of California, Los Angeles (UCLA) United States
18. Northwestern University United States
19. University of Illinois at Urbana-Champaign United States
20. Brown University United States
21. Purdue University United States
22. University of Texas at Austin United States
23. Boston University United States
24. Georgia Institute of Technology United States
25. University of North Carolina, Chapel Hill United States
26. Ohio State University United States
27. University of Pittsburgh United States
Engineering & T
Life Sciences &
Natural Science
Employer reputa
Citations per fac

LineUp



"It's really complex to
make something simple…"

Jack Dorsey (creator of Twitter)



University

MIT, USA
Harvard, USA
Princeton, USA
Cambridge, UK
Oxford, UK

10 Requirements

Encode Rank

10 Requirements

1. Encode Rank

University

MIT, USA
Harvard, USA
Princeton, USA
Cambridge, UK
Oxford, UK

Rank	University

1. MIT, USA
2. Harvard, USA
3. Princeton, USA
4. Cambridge, UK
5. Oxford, UK

10 Requirements

1. Encode Rank

Encode Cause of Rank

10 Requirements

1. Encode Rank
2. Encode Cause of Rank

Rank	University
1.	MIT, USA
2.	Harvard, USA
3.	Princeton, USA
4.	Cambridge, UK
5.	Oxford, UK

Rank	University	Score
1.	MIT, USA	89.4
2.	Harvard, USA	84.2
3.	Princeton, USA	73.8
4.	Cambridge, UK	64.3
5.	Oxford, UK	44.0

Rank	University	Score
1.	MIT, USA	
2.	Harvard, USA	
3.	Princeton, USA	
4.	Cambridge, UK	
5.	Oxford, UK	

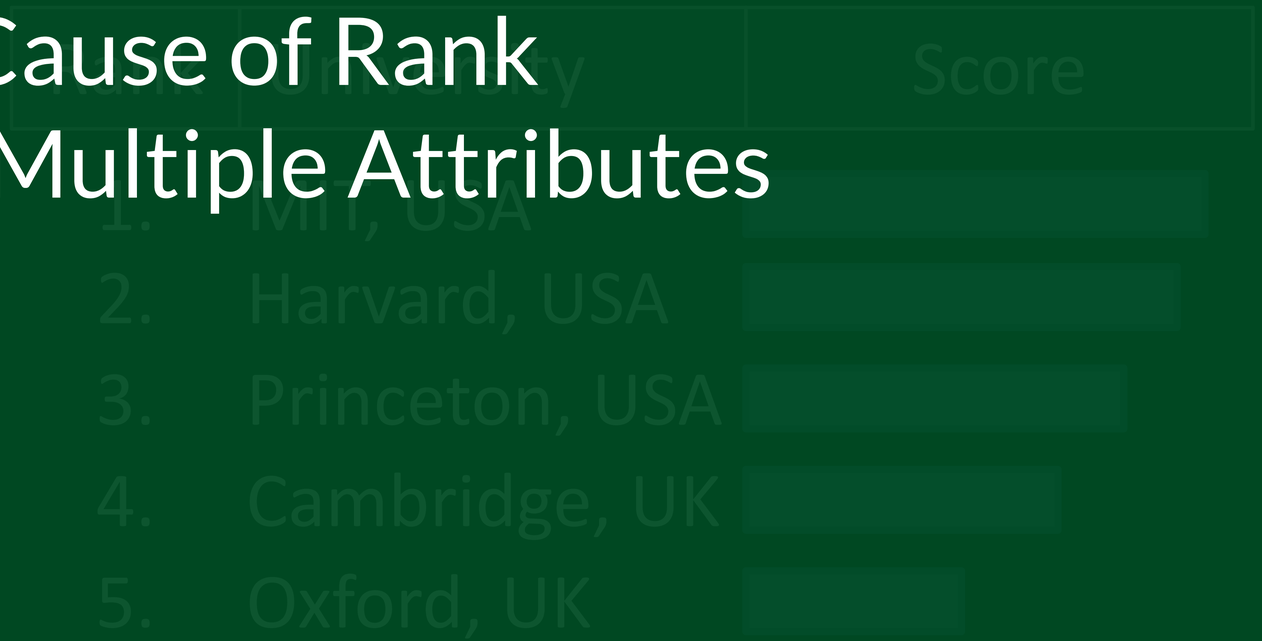
10 Requirements

1. Encode Rank
2. Encode Cause of Rank

Support Multiple Attributes

10 Requirements

1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes



Score = f(A, B, C)

Rank	University	Score	A	B	C
1.	MIT, USA				
2.	Harvard, USA				
3.	Princeton, USA				
4.	Cambridge, UK				
5.	Oxford, UK				

Combiner functions: f(A,B,C)

(Weighted) sum

$Score = w_a A + w_b B + w_c C$

Combiner functions: f(A,B,C)

(Weighted) sum

$Score = w_a A + w_b B + w_c C$

Maximum

$Score = max(A, B, C)$

Combiner functions: f(A,B,C)

(Weighted) sum

$Score = w_a A + w_b B + w_c C$

Maximum

$Score = max(A, B, C)$

Product

Nesting

…

Combiner functions: f(A,B,C)

(Weighted) sum

$Score = w_a A + w_b B + w_c C$

→ Serial

Maximum

$Score = max(A, B, C)$

→ Parallel

Product

Nesting

…

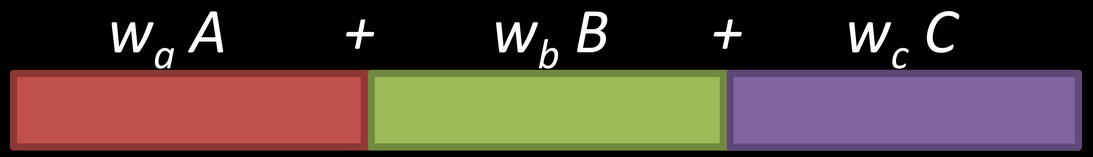
→ Complex Combiners

Serial Combiner

$w_a A + w_b B + w_c C$

Rank	University	A	B	C
1.	MIT, USA			
2.	Harvard, USA			
3.	Princeton, USA			
4.	Cambridge, UK			
5.	Oxford, UK			

Serial Combiner (as Stacked Bar)



Rank	University	A	B	C
1.	MIT, USA			
2.	Harvard, USA			
3.	Princeton, USA			
4.	Cambridge, UK			
5.	Oxford, UK			

Serial Combiner (as Stacked Bar)

$w_a\,A \quad + w_b\,B + \quad w_c\,C$

Rank	University	A	B	C
1.	MIT, USA			
2.	Harvard, USA			
3.	Princeton, USA			
4.	Cambridge, UK			
5.	Oxford, UK			

Serial Combiner (as Stacked Bar)

$w_a A + w_b B + w_c C$

Rank	University	A	B	C
1.	MIT, USA			
2.	Harvard, USA			
3.	Princeton, USA			
4.	Cambridge, UK			
5.	Oxford, UK			

Serial Combiner (as Stacked Bar)

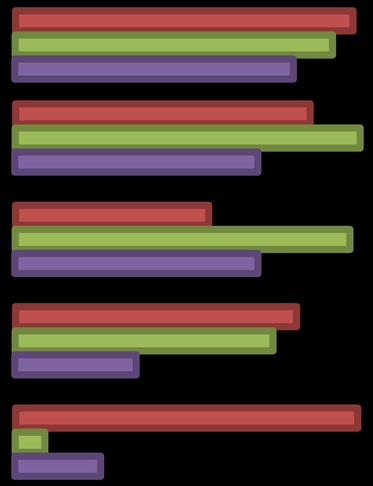
Rank	University	A	B	C
1.	MIT, USA			
2.	Harvard, USA			
3.	Oxford, UK			
4.	Cambridge, UK			
5.	Princeton, USA			

Parallel Combiner

Rank	University	A	B	C
1.	MIT, USA			
2.	Harvard, USA			
3.	Princeton, USA			
4.	Cambridge, UK			
5.	Oxford, UK			

Parallel Combiner (as Multi Bar)

Rank	University	MAX(A,B,C)
1.	MIT, USA	
2.	Harvard, USA	
3.	Princeton, USA	
4.	Cambridge, UK	
5.	Oxford, UK	



Parallel Combiner (as Multi Bar)

Rank	University	MAX(A,B,C)
1.	MIT, USA	
2.	Harvard, USA	
3.	Princeton, USA	
4.	Cambridge, UK	
5.	Oxford, UK	

Parallel Combiner (as Multi Bar)

Rank	University	MAX(A,B,C)
1.	Oxford, UK	
2.	Harvard, USA	
3.	MIT, USA	
4.	Princeton, USA	
5.	Cambridge, UK	

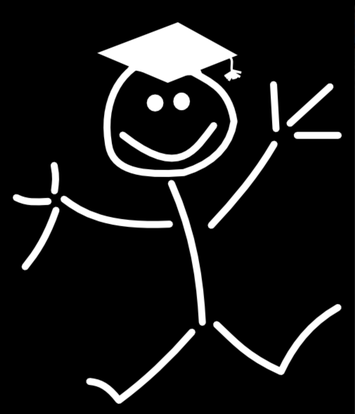
10 Requirements

1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes

Interactive Refinement and Visual Feedback

10 Requirements

1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Refinement and Visual Feedback



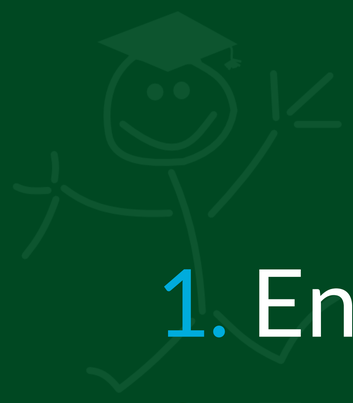
128 visible of 906 (14.13%)

Ran	School Name	Country	Faculty/student ratio	Employer reputation	Citations per faculty
	Filter: <None>	Filter: 2 out of 72			
1.	American University	United States			
2.	Arizona State University	United States			
3.	Aston University	United Kingdom			
4.	Birkbeck College, University of L	United Kingdom			
5.	Boston College	United States			
6.	Boston University	United States			
7.	Brandeis University	United States			
8.	Brown University	United States			
9.	Brunel University	United Kingdom			
10.	California Institute of Technology	United States			
11.	Cardiff University	United Kingdom			
12.	Case Western Reserve University	United States			
13.	City University London	United Kingdom			
14.	College of William & Mary	United States			
15.	Colorado State University	United States			
16.	Columbia University	United States			
17.	Cornell University	United States			
18.	Cranfield University	United Kingdom			
19.	Dartmouth College	United States			
20.	Drexel University	United States			
21.	Duke University	United States			
22.	Durham University	United Kingdom			

10 Requirements

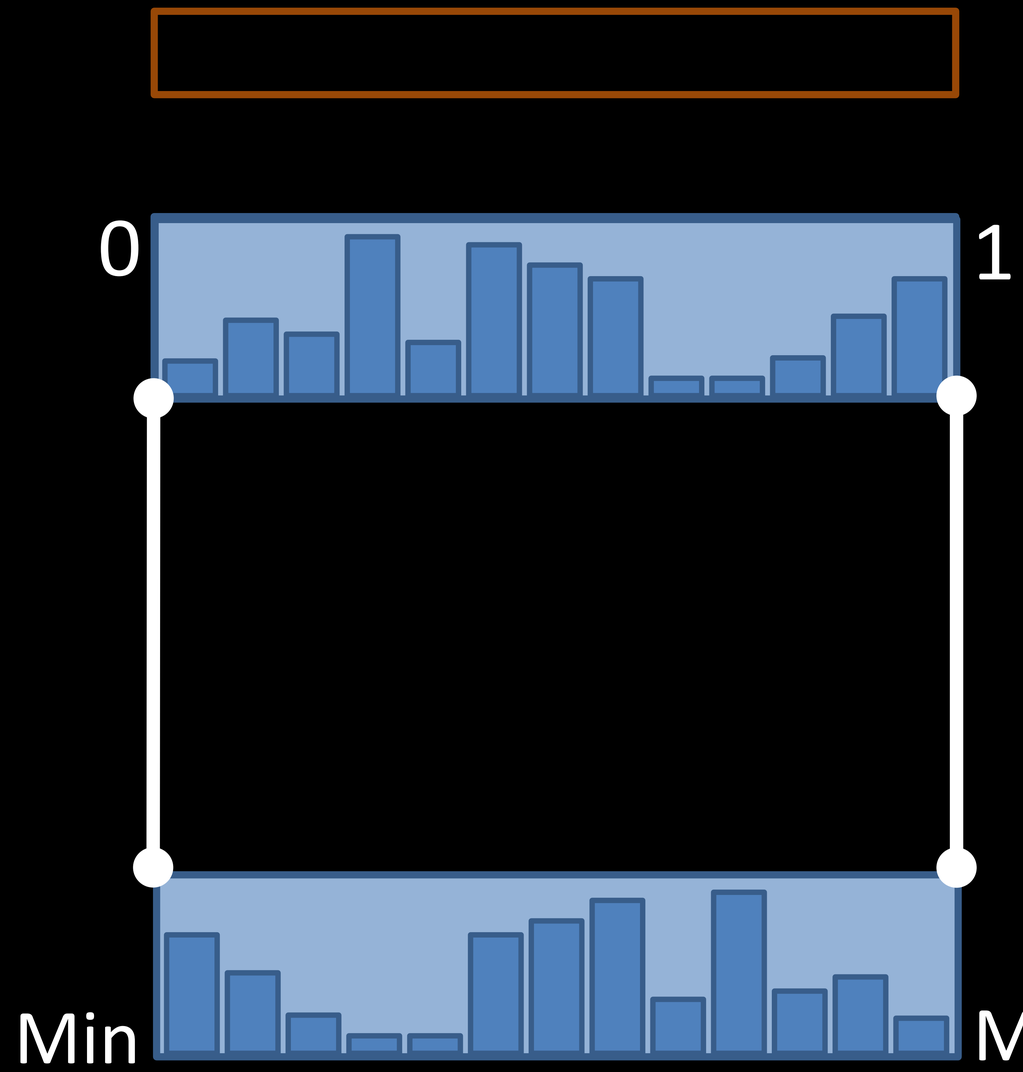
1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Attribute Selection and Visual Feedback

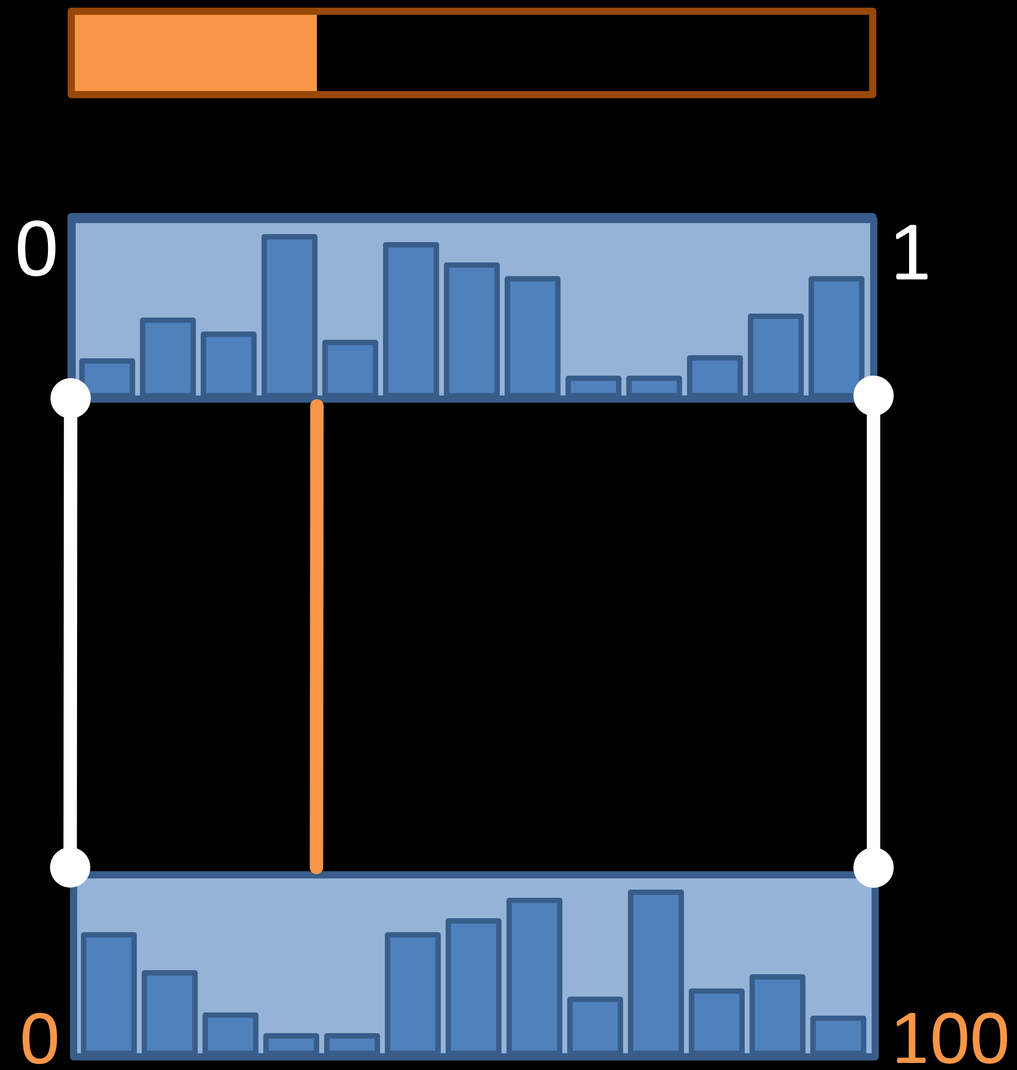
Flexible Mapping of Attributes to Scores



10 Requirements

1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Refinement and Visual Feedback
5. Flexible Mapping of Attributes to Scores


0
1
Min
Max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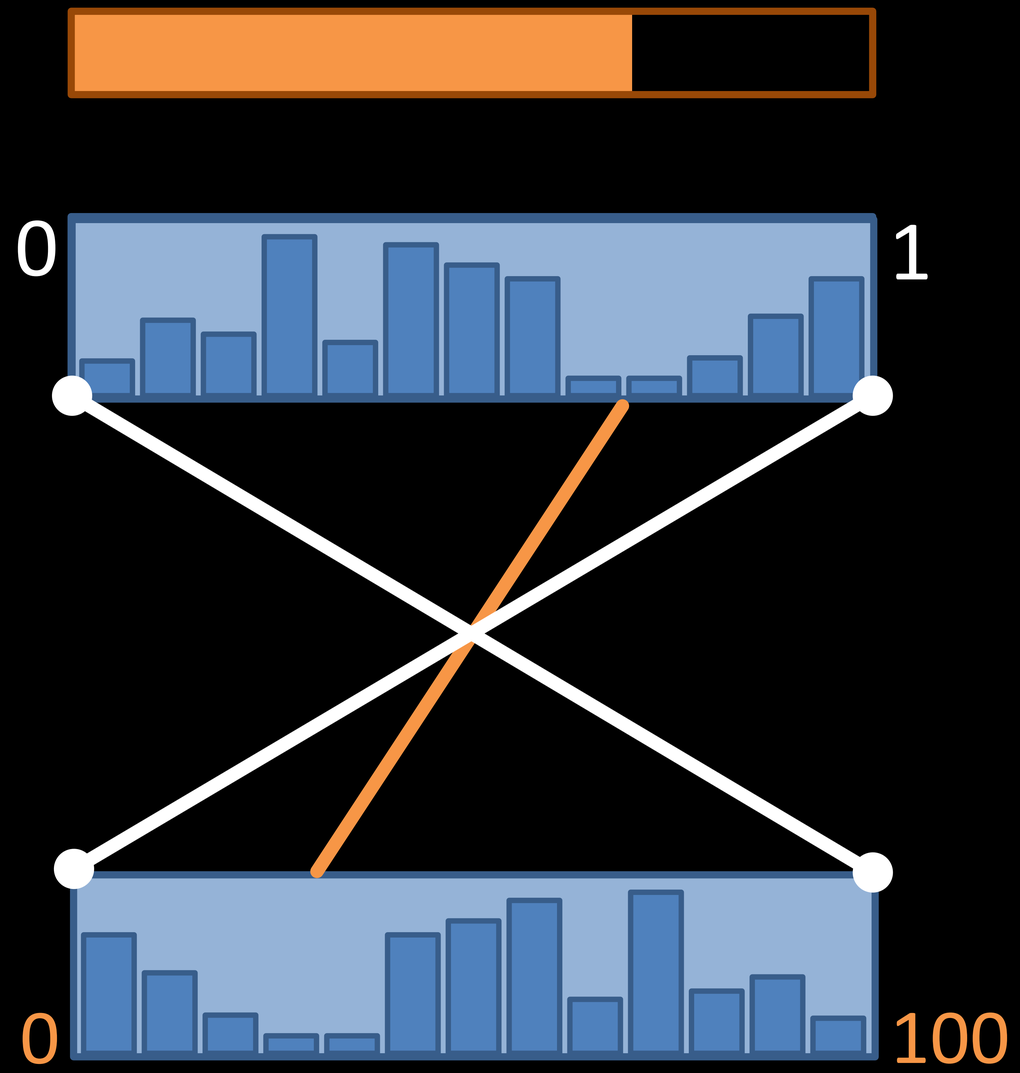
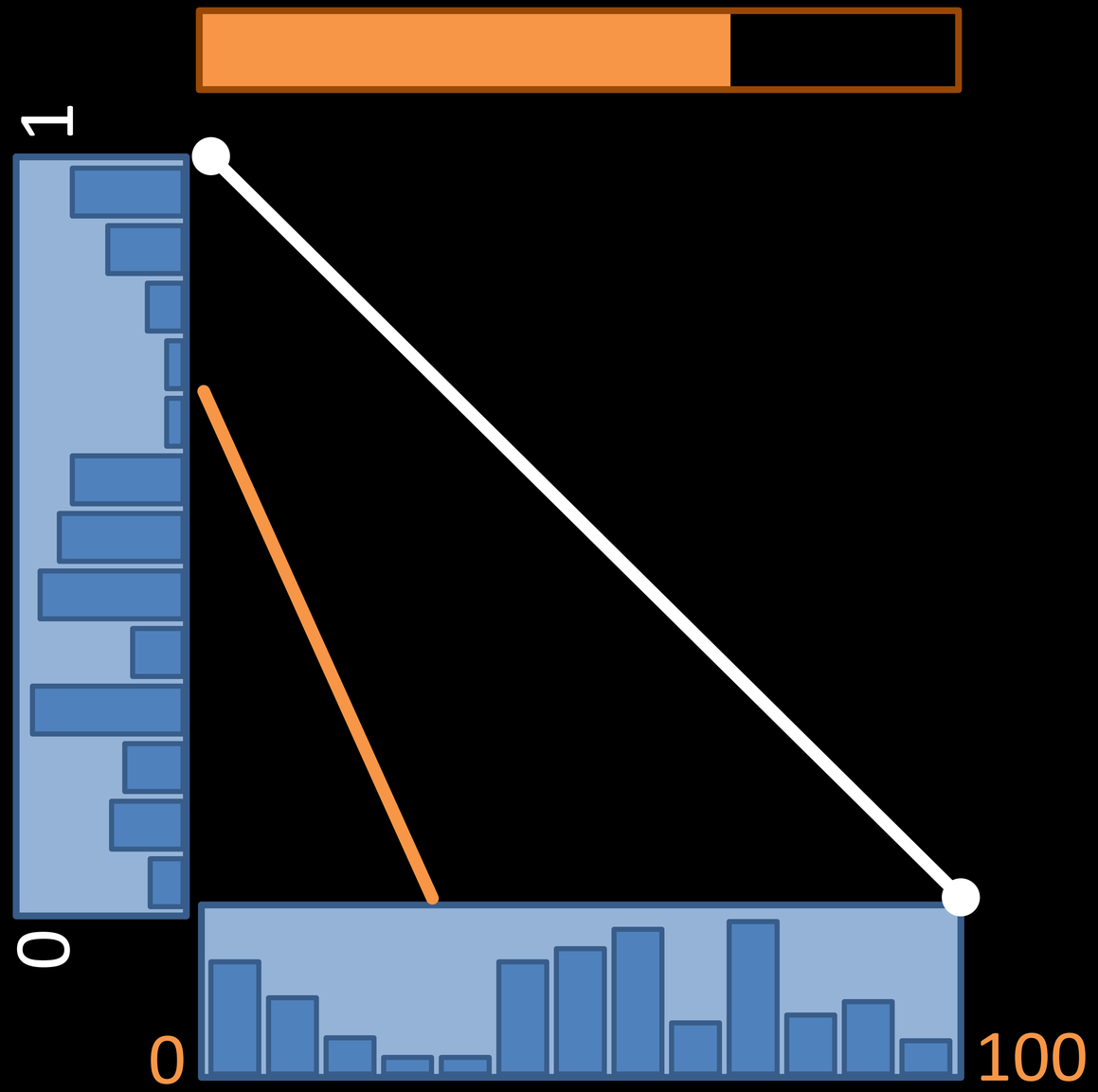
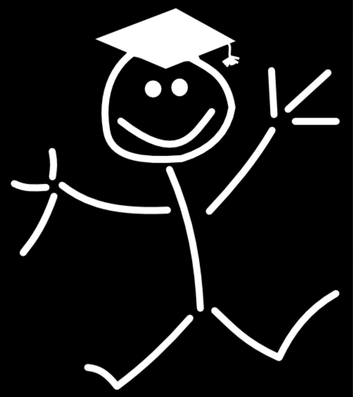
1
0
100


0
1
0
100


1
0
0
100



93 visible of 399 (23.31%)

SUM (Engineering & Technology, Arts & Humanities, Life Sciences & Medicine)

33.33% 33.33% 33.33%

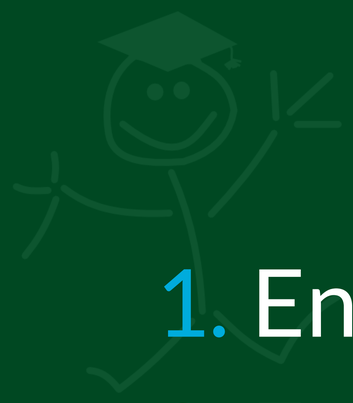
Engineering & Technology | Arts & Humanities | Life Sciences & Medicine

Ran	School Name	Country
	Filter: <None>	Filter: 2 out of 43
1.	University of Oxford	United Kingdom
2.	University of Cambridge	United Kingdom
3.	Harvard University	United States
4.	Stanford University	United States
5.	Massachusetts Institute of Technology (MIT	United States
6.	University of California, Berkeley (UCB)	United States
7.	University of California, Los Angeles (UCL	United States
8.	Yale University	United States
9.	UCL (University College London)	United Kingdom
10.	Columbia University	United States
11.	Princeton University	United States
12.	University of Edinburgh	United Kingdom
13.	University of Michigan	United States
14.	Cornell University	United States
15.	University of Pennsylvania	United States
16.	The University of Manchester	United Kingdom
17.	Imperial College London	United Kingdom
18.	University of Chicago	United States

10 Requirements

1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Refinement and Visual Feedback
5. Flexible Mapping of Attributes to Scores

Compare Rankings



10 Requirements

1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Refinement and Visual Feedback
5. Flexible Mapping of Attributes to Scores
6. Compare Rankings

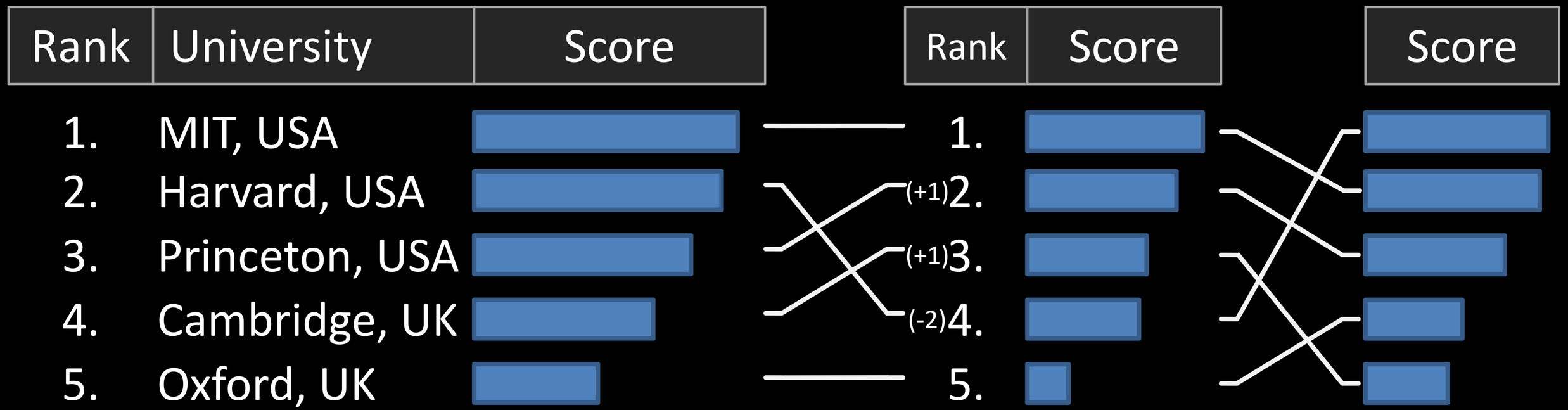
Rank	University	Score
1.	MIT, USA	
2.	Harvard, USA	
3.	Princeton, USA	
4.	Cambridge, UK	
5.	Oxford, UK	

Rank	University	Score
1.	MIT, USA	
2.	Harvard, USA	
3.	Princeton, USA	
4.	Cambridge, UK	
5.	Oxford, UK	

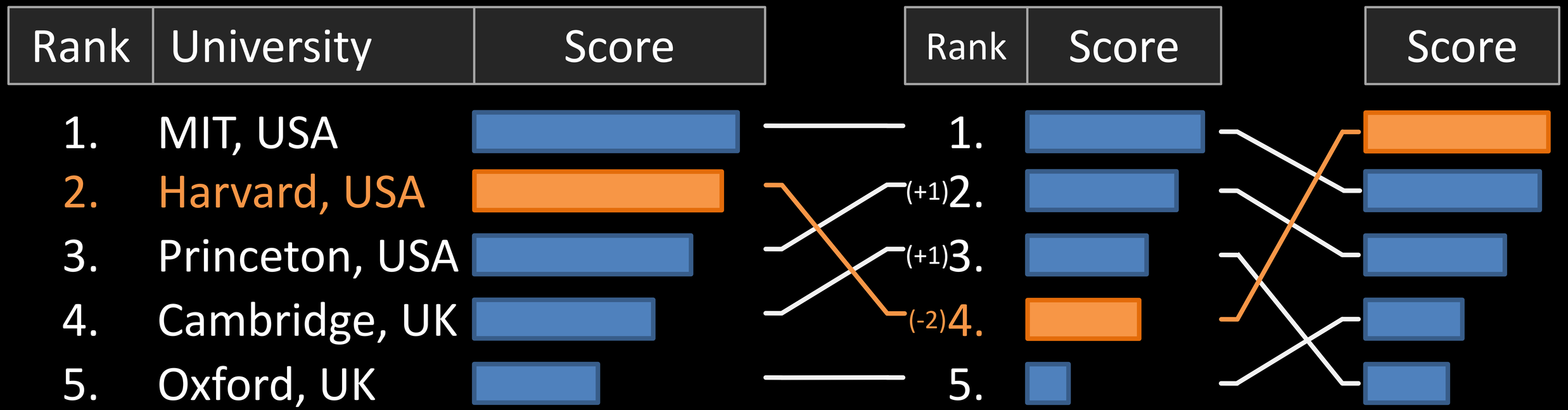
Rank	Score
1.	
2.	
3.	
4.	
5.	

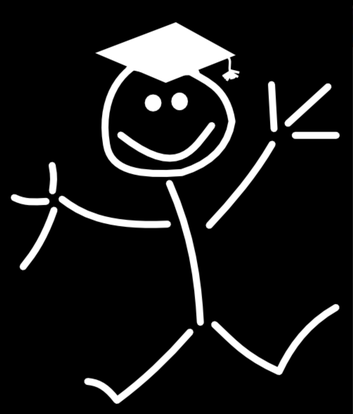
Score

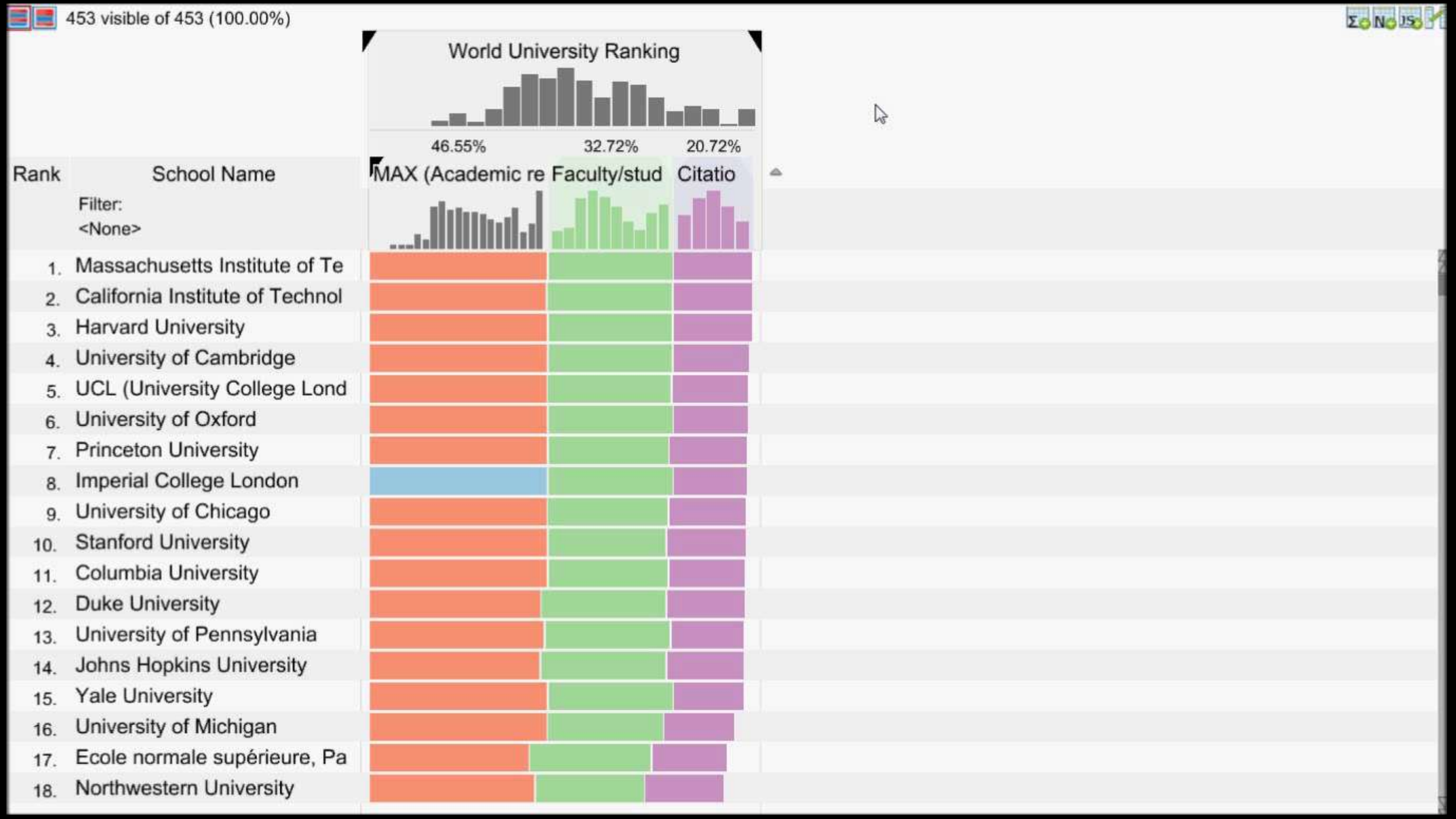
Bump Charts


Rank
University
Score
1. MIT, USA
2. Harvard, USA
3. Princeton, USA
4. Cambridge, UK
5. Oxford, UK
Rank
Score
1.
(+1)2.
(+1)3.
(-2)4.
5.
Score

Bump Charts


Rank
University
Score
1. MIT, USA
2. Harvard, USA
3. Princeton, USA
4. Cambridge, UK
5. Oxford, UK
Rank
Score
1.
(+1)2.
(+1)3.
(-2)4.
5.
Score

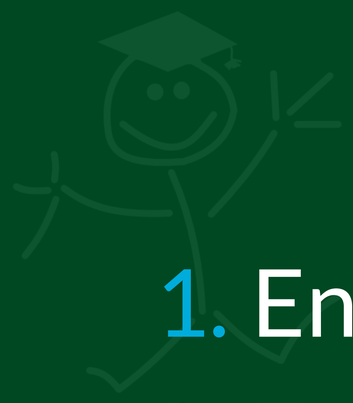



453 visible of 453 (100.00%)
World University Ranking
46.55%
32.72%
20.72%
Rank
School Name
MAX (Academic re
Faculty/stud
Citatio
Filter:
<None>
1. Massachusetts Institute of Te
2. California Institute of Technol
3. Harvard University
4. University of Cambridge
5. UCL (University College Lond
6. University of Oxford
7. Princeton University
8. Imperial College London
9. University of Chicago
10. Stanford University
11. Columbia University
12. Duke University
13. University of Pennsylvania
14. Johns Hopkins University
15. Yale University
16. University of Michigan
17. Ecole normale supérieure, Pa
18. Northwestern University

10 Requirements

1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Refinement and Visual Feedback
5. Flexible Mapping of Attributes to Scores
6. Compare Rankings

Scalability

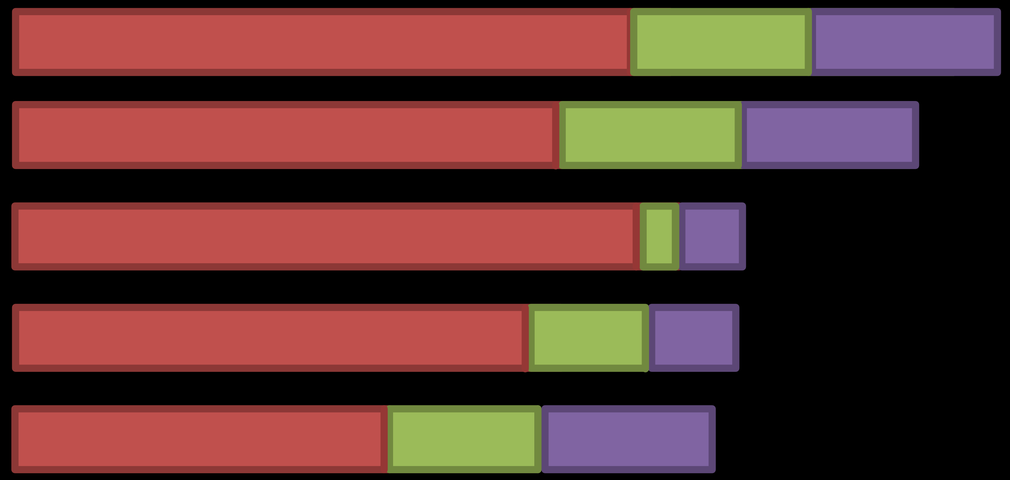


10 Requirements

1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Refinement and Visual Feedback
5. Flexible Mapping of Attributes to Scores
6. Compare Rankings
7. Scalability

Scalability

Rank	University	A	B	C
1.	MIT, USA			
2.	Harvard, USA			
3.	Oxford, UK			
4.	Cambridge, UK			
5.	Princeton, USA			



Scalability

Rank	University	Score
1.	MIT, USA	
2.	Harvard, USA	
3.	Oxford, UK	
4.	Cambridge, UK	
5.	Princeton, USA	

Scalability

Rank	University	
1.	MIT, USA	
2.	Harvard, USA	
3.	Oxford, UK	
4.	Cambridge, UK	
5.	Princeton, USA	

Scalability

Rank	University	
1.	MIT, USA	
2.	Harvard, USA	
3.	Oxford, UK	
4.	Cambridge, UK	
5.	Princeton, USA	

10 Requirements

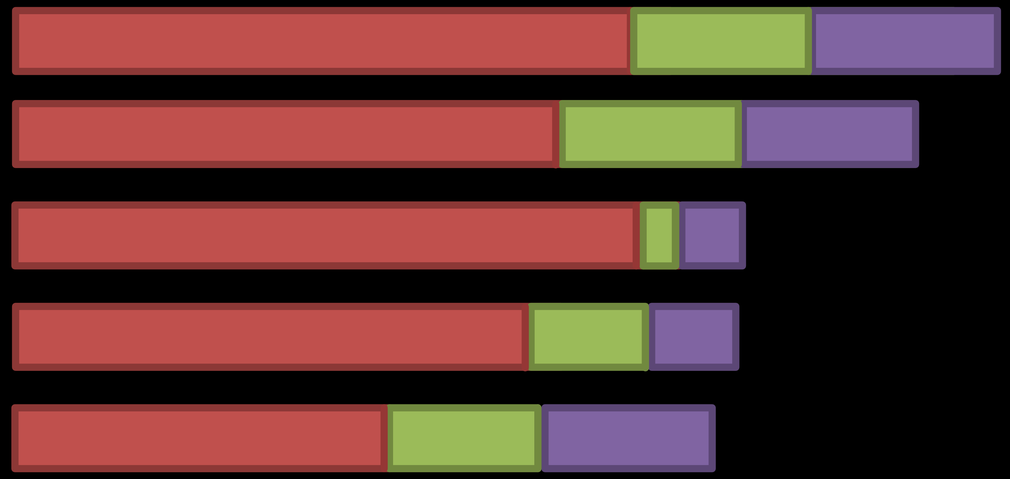
1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Refinement and Visual Feedback
5. Flexible Mapping of Attributes to Scores
6. Compare Rankings
7. Scalability

10 Requirements

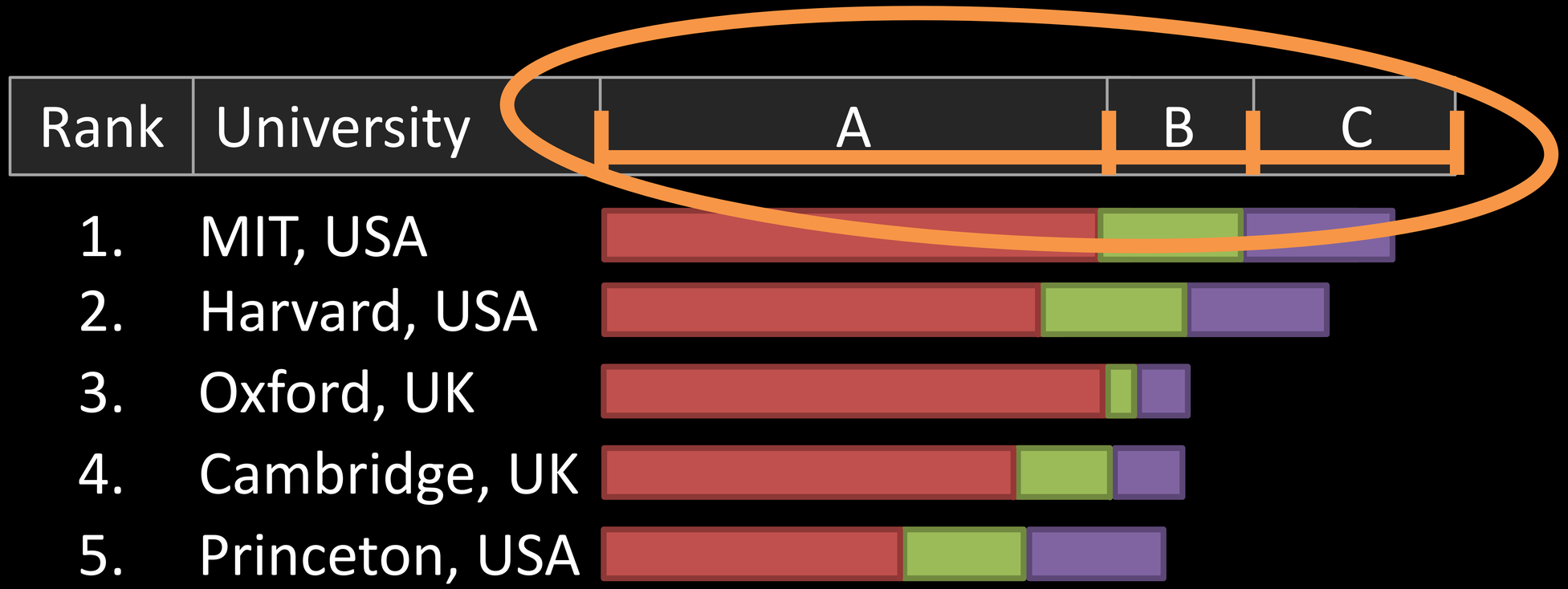
1. Encode Rank
2. Encode Cause of Rank
3. Support Multiple Attributes
4. Interactive Refinement and Visual Feedback
5. Flexible Mapping of Attributes to Scores
6. Compare Rankings
7. Scalability
8. Filtering
9. Handle Missing Values
10. Optimization

Optimization

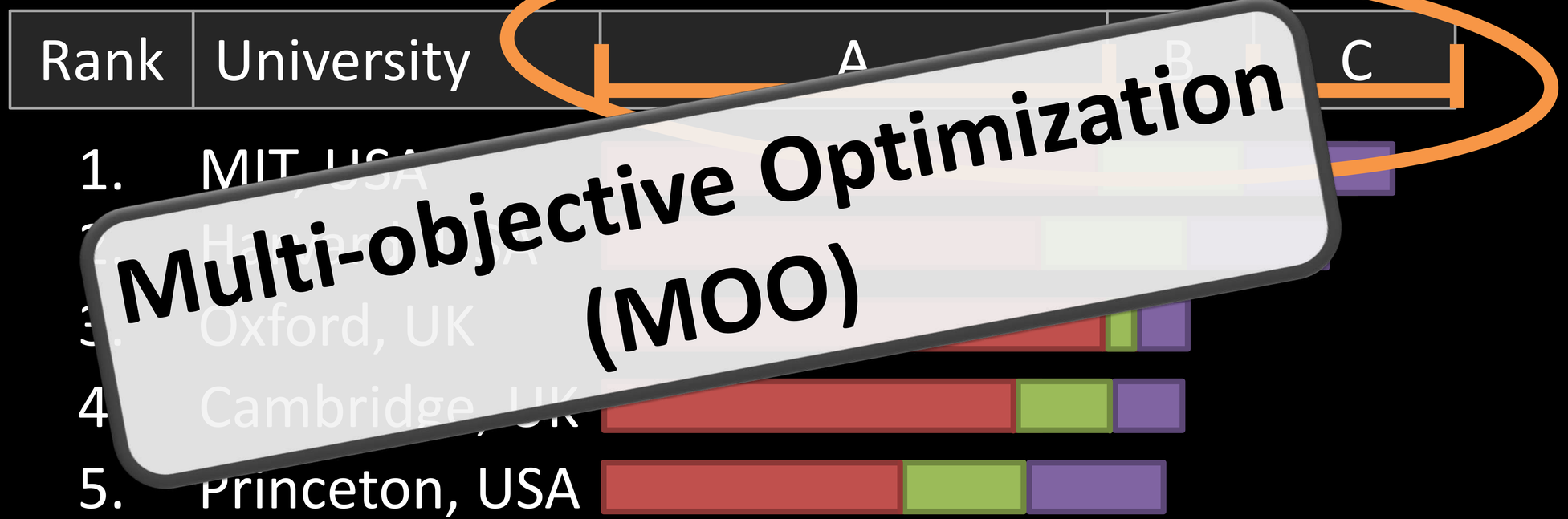
Rank	University	A	B	C
1.	MIT, USA			
2.	Harvard, USA			
3.	Oxford, UK			
4.	Cambridge, UK			
5.	Princeton, USA			



Optimization



Optimization



Implementation

CALEYDO

http://caleydo.org

Open source (BSD 3)

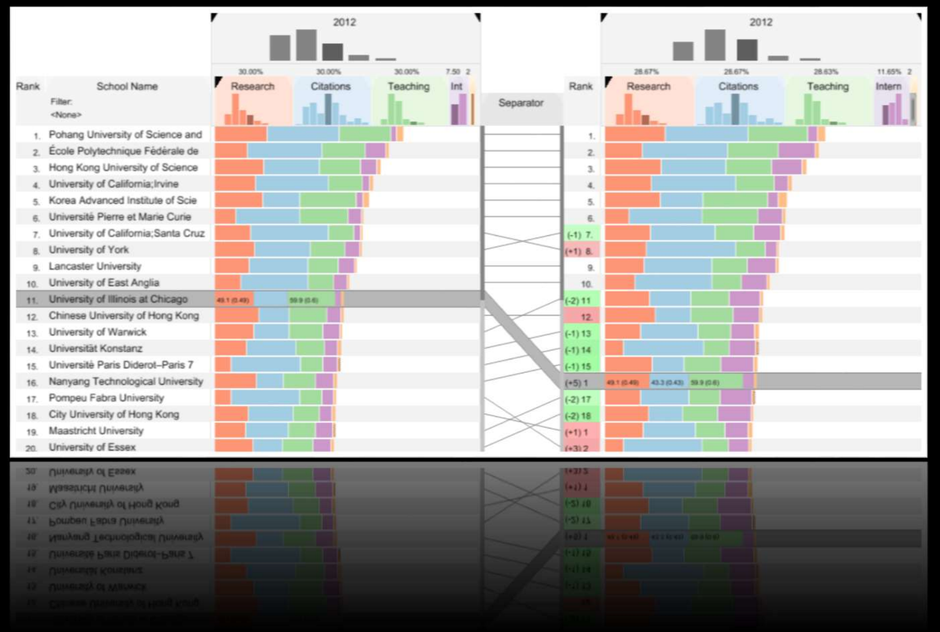
Source code on GitHub: https://github.com/Caleydo

Demos, videos, and more: http://lineup.caledyo.org

Summary

10 requirements for an intuitive interactive multi-attribute ranking tool

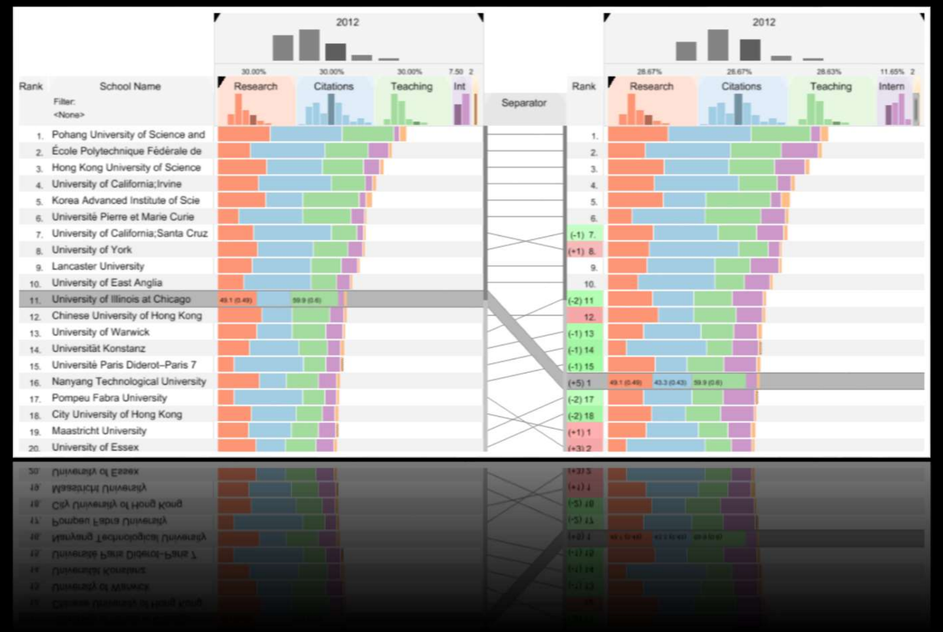
LineUp visualization technique



Summary

10 requirements for an intuitive interactive multi-attribute ranking tool

LineUp visualization technique

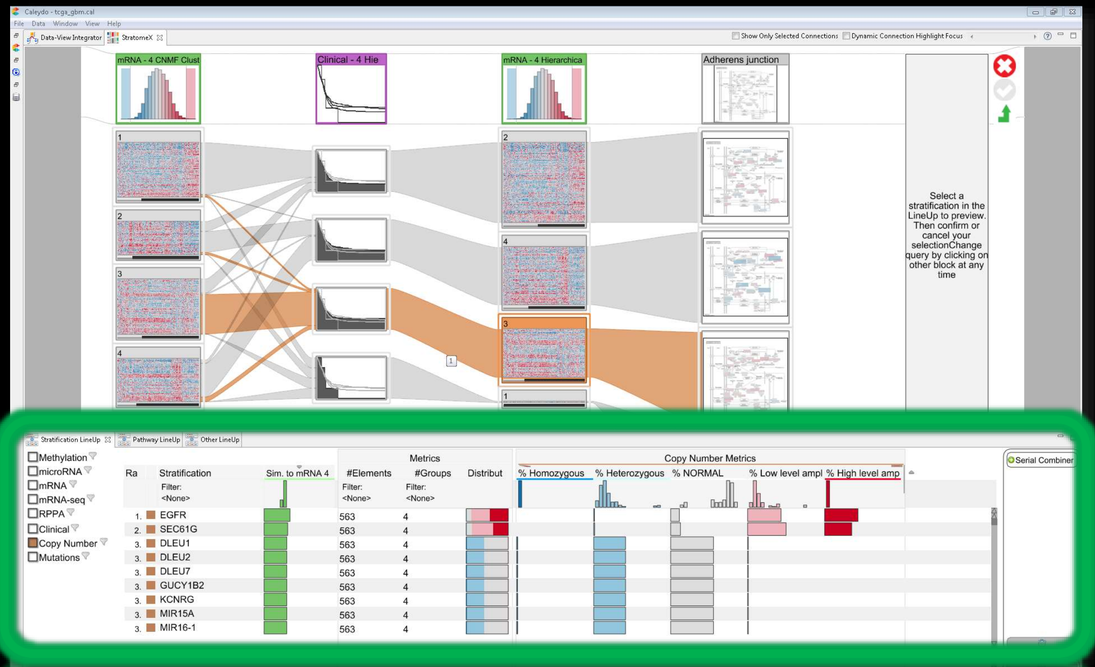


Future Work

Web port

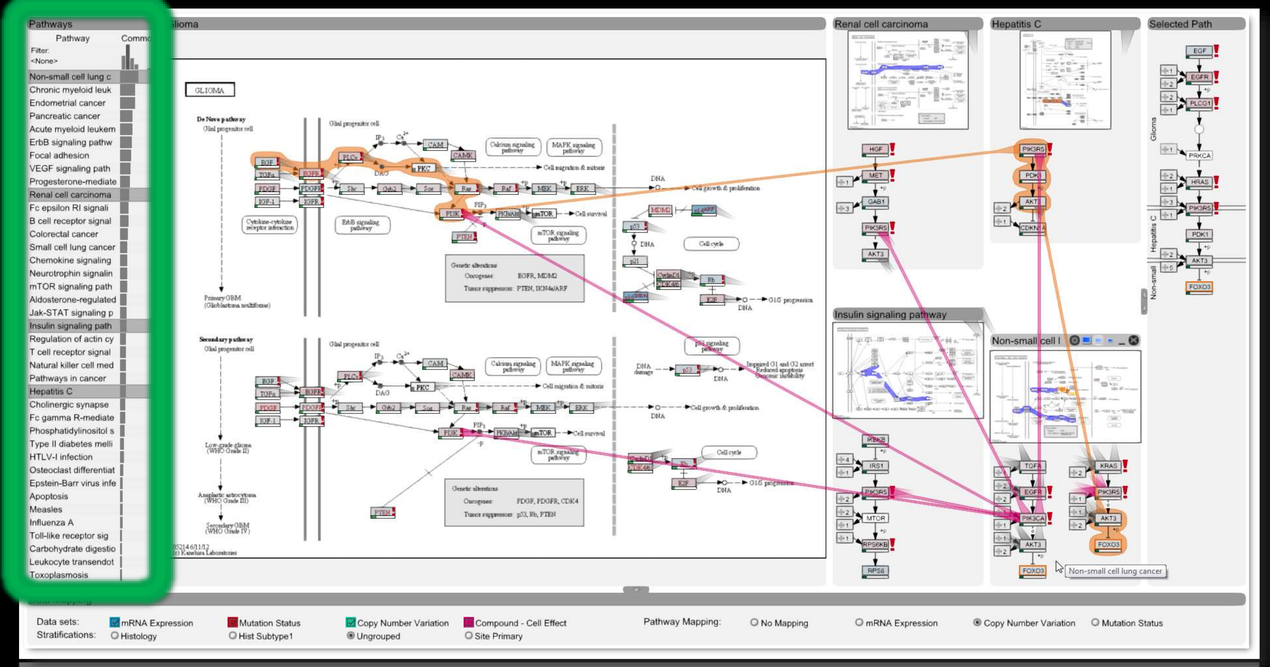
Integrate optimization algorithms

LineUp Applications



StratomeX

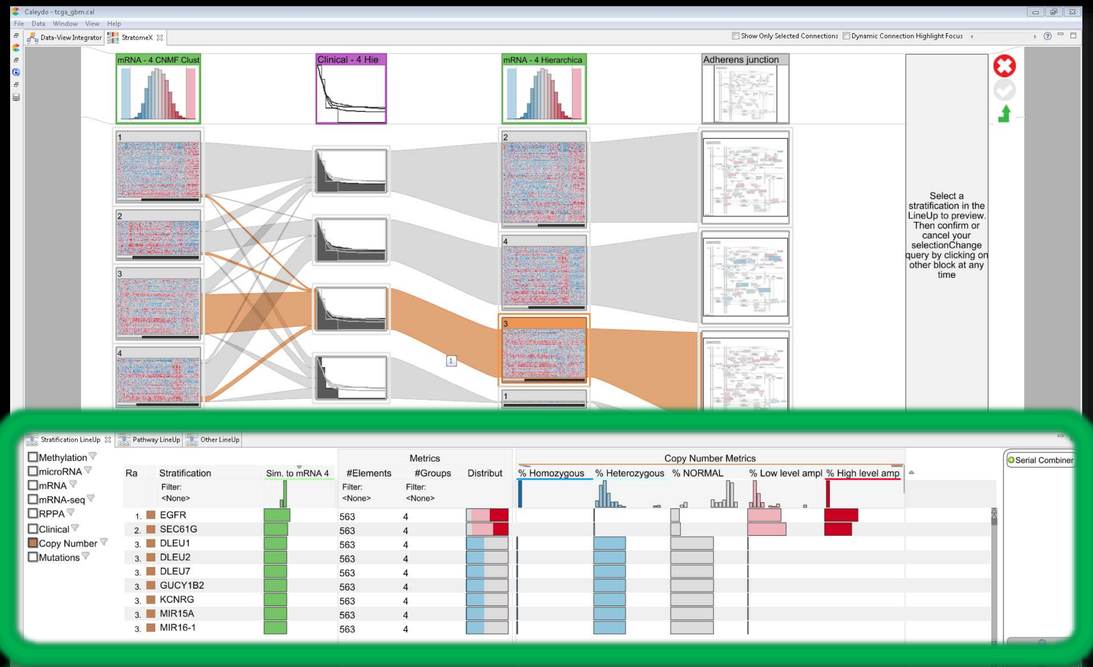
Cancer Subtype Analysis

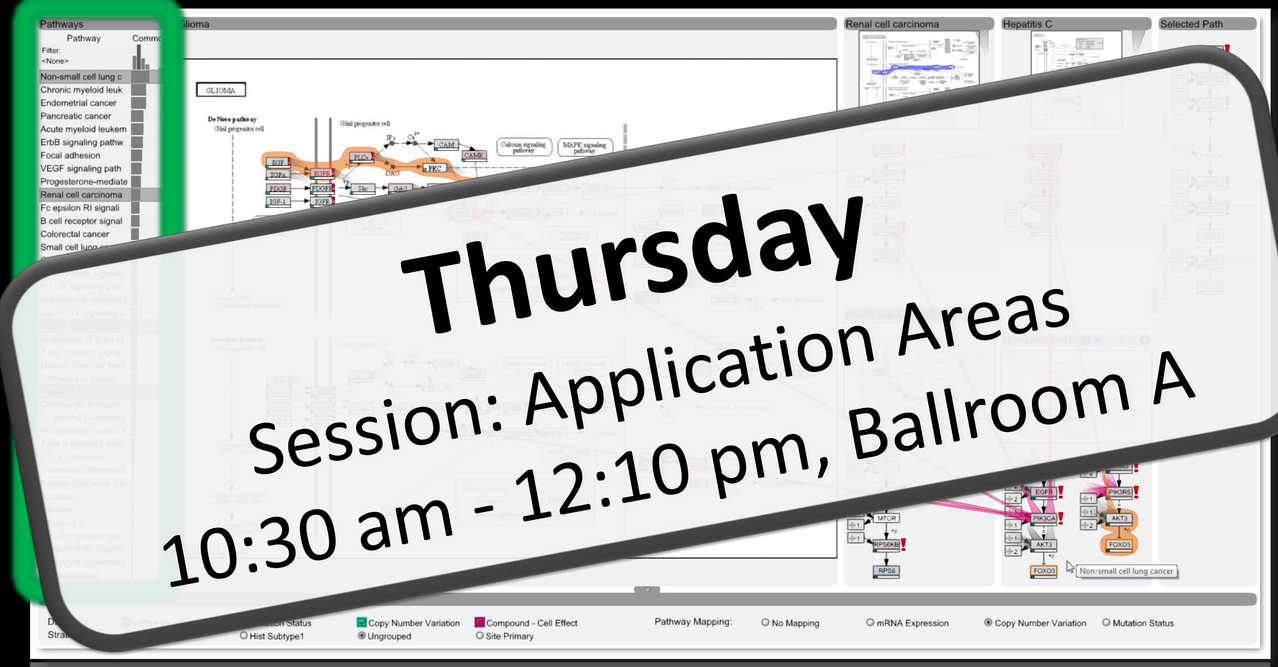


Entourage

Pathway Analysis

LineUp Applications





Thursday

Session: Application Areas

10:30 am - 12:10 pm, Ballroom A

StratomeX

Cancer Subtype Analysis

Entourage

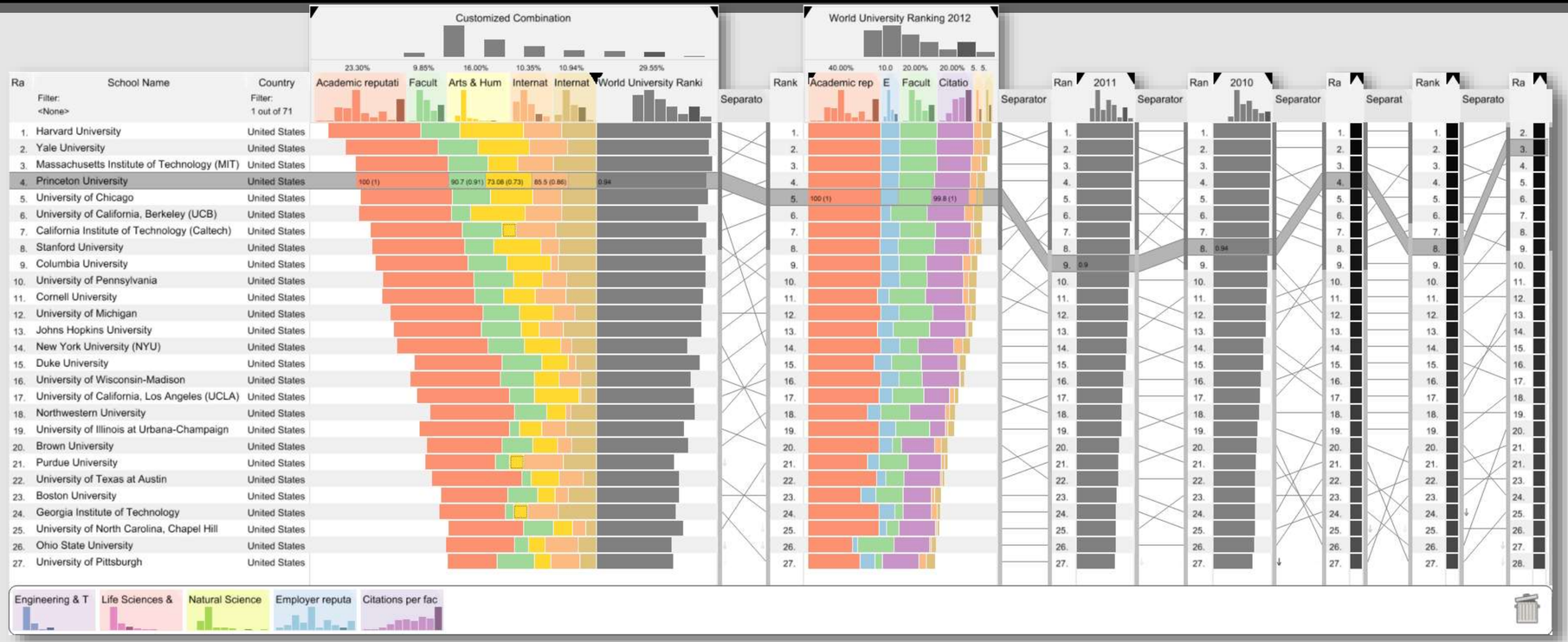
Pathway Analysis

LineUp

Visual Analysis of Multi-Attribute Rankings

Samuel Gratzl, Alexander Lex, Nils Gehlenborg, Hanspeter Pfister, and Marc Streit

CALEYDO



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