

Simple Models for the Complex Problem of Measuring and Improving Sustainable Development

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Outline

- The problem
- Rationale for selecting certain solutions for today
- Solution from Humboldt State University
- Solution from Zhejiang University
- Other cool math
- Conclusions and Discussion



The Problem

The Problem (well first...)

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- Sustainable Development
 - What is it?
 - Why is it hard?
 - Who is thinking about this issue?
 - Why is it important?

The Problem

- Part 1:
 - Develop a way to compare/rank the sustainable development of a nation
 - Validate the methodology
- Part 2:
 - Select one of nations of the UN's list of 40 least developed nations
 - Develop a specific targeted action plan to advance that nation's level of sustainable development

Commonly used data

- World Bank

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- World Bank

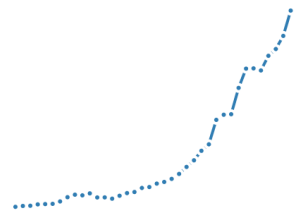
Bhutan ⓘ			
Country Profile			
	1990	2000	2010
World view			
Population, total (millions)	0.53	0.59	0.69
Population growth (annual %)	1.6	2.2	1.1
Surface area (sq. km) (thousands)	47.0	40.1	38.4
Population density (people per sq. km of land area)	11.4	14.8	18.0
Poverty headcount ratio at national poverty lines (% of population)	12.0
Poverty headcount ratio at \$1.90 a day (2011 PPP) (% of population)	..	17.6	2.2
GNI, Atlas method (current US\$) (billions)	0.31	0.44	1.43
GNI per capita, Atlas method (current US\$)	580	740	2,090
GNI, PPP (current international \$) (billions)	0.76	1.61	4.32
GNI per capita, PPP (current international \$)	1,430	2,730	6,300
People			
Income share held by lowest 20%	..	6.5	6.7
Life expectancy at birth, total (years)	53	61	68
Fertility rate, total (births per woman)	5.5	3.5	2.3
Adolescent fertility rate (births per 1,000 women ages 15-19)	104	77	36
Contraceptive prevalence, any methods (% of women ages 15-49)	..	31	66
Births attended by skilled health staff (% of total)	..	24	65
Mortality rate, under-5 (per 1,000 live births)	127	78	43
Prevalence of underweight, weight for age (% of children under 5)	34.0	14.1	12.8
Immunization, measles (% of children ages 12-23 months)	93	78	95
Primary completion rate, total (% of relevant age group)	19	51	87
School enrollment, primary (% gross)	51.4	76.2	108.2

Bhutan ⓘ

GDP (current US\$)

[Details](#)

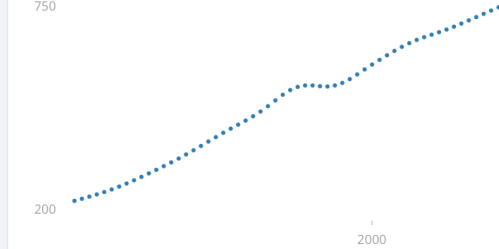
Billion
2.5



Population, total

[Details](#)

Thousand
750



CO2 emissions (metric tons per capita)

[Details](#)

2



Life expectancy at birth, total (year)

[Details](#)

All Countries and Economies

Country	Most Recent Year	Most Recent Value	
Afghanistan	2018	520.9	
Albania	2018	5,268.8	
		4,114.7	
		11,466.7	
		42,029.8	
		3,432.4	
		16,727.0	
		11,683.9	
		4,212.1	



Download

[CSV](#) [XML](#) [EXCEL](#)

DataBank

Online tool for visualization and analysis



Country Profile



How did I pick the solutions we will discuss?

From Humboldt State University

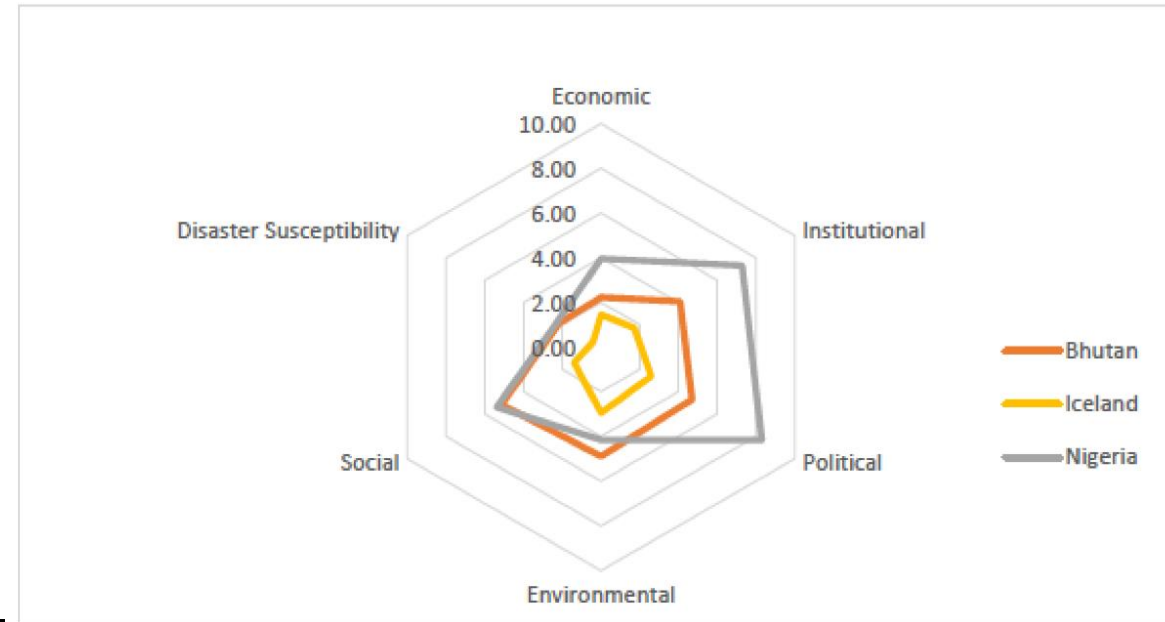
- Methodology overview:
 - Identified six domains
 - Economics, Risk, Social, Environmental, Political, Institutional
 - Identified country-specific data to create a metric score for each domain
 - So far – this was a common approach, so why was this paper outstanding?

From Humboldt State University

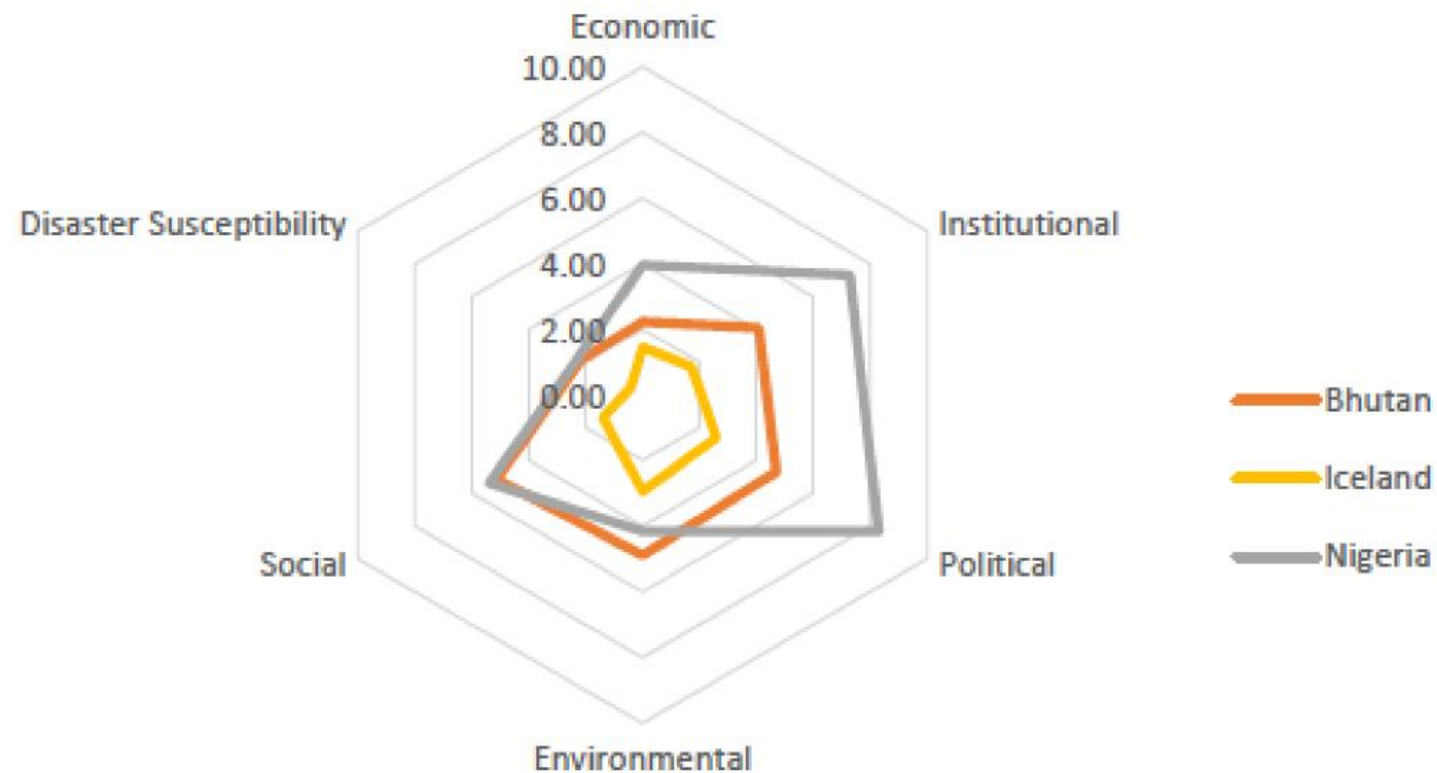
- Strengths:
 - Clear rationale for selection of choices
 - Excellent link between mathematical choices and real world – clear and convincing discussion!
 - Did *NOT* try to collapse these six domains into a single integrated metric (which was a common approach)
 - So, what did they do instead?

From Humboldt State University

- Radar Plot
 - Used a radar plot visualization
 - Allowed more targeted suggestions for the country-specific 20-year plan (Bhutan)
 - Allowed a better way to show the outcome of implementing the 20-year plan



From Humboldt State University



What level of math was needed?

- For each domain, they made and justified a linear weighted metric involving factors that they noted as relevant
- They made a radar plot - more about creativity than "math knowledge"
- The beauty of this solution is the simplicity - any national leader could understand their logic, their methodology, and their findings.

From Zhejiang University

- Methodology Overview
 - As with many teams, this Outstanding paper distilled country data into two indices: socio-economic and environmental
 - They used many of the same approaches as other teams to make their indices (PCA and entropy-based weighting scheme)
 - So, why is this solution special?

From Zhejiang University

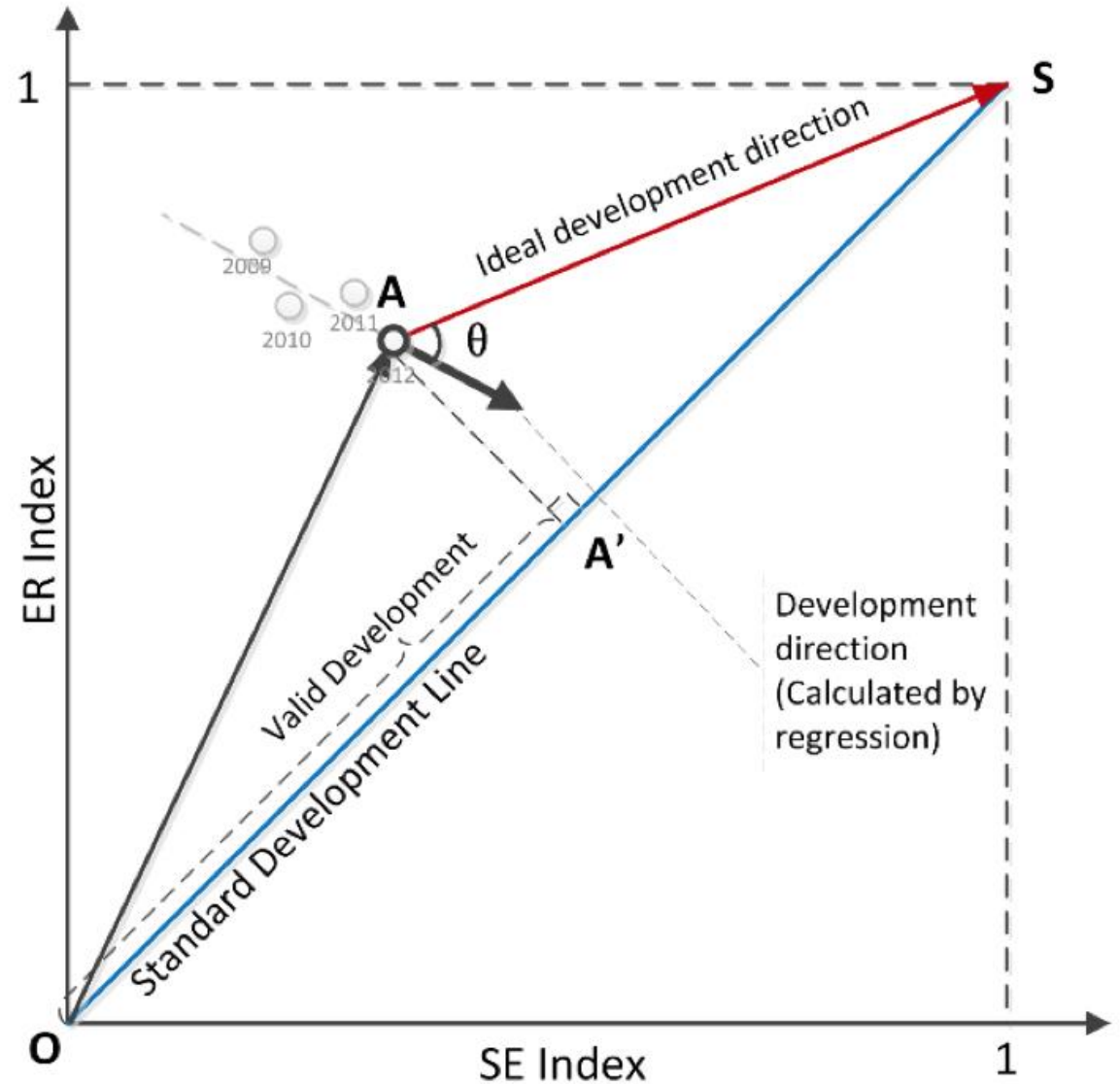
- Strength
 - Development of an angle-based measure!
 - Goal was to be balanced between the two indices, so living along a $y=x$ line
 - “Harmonious development measure” defined as the magnitude of the intersection angle between the ideal development direction and the actual development direction of a nation through regression analysis

From Zhejiang University

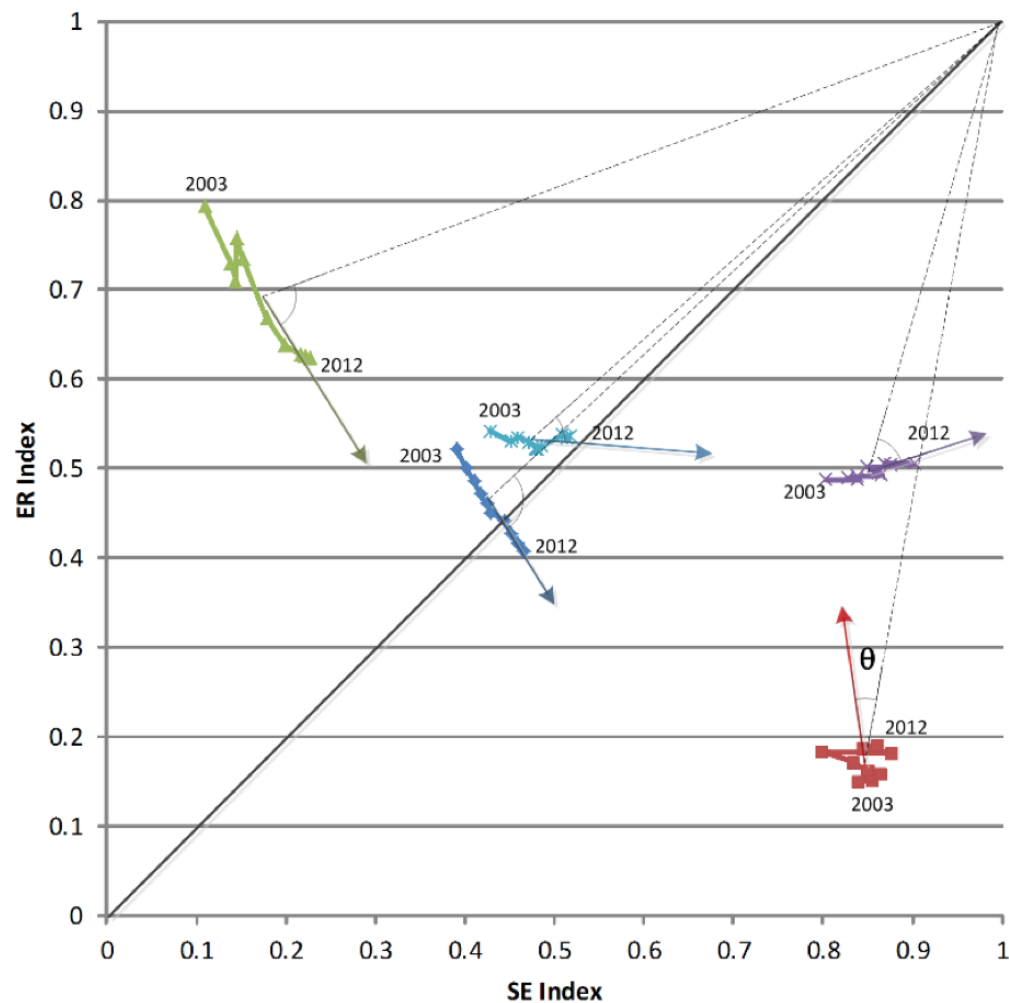
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- Wait! This sounds confusing! How is that good...?

From Zhejiang University

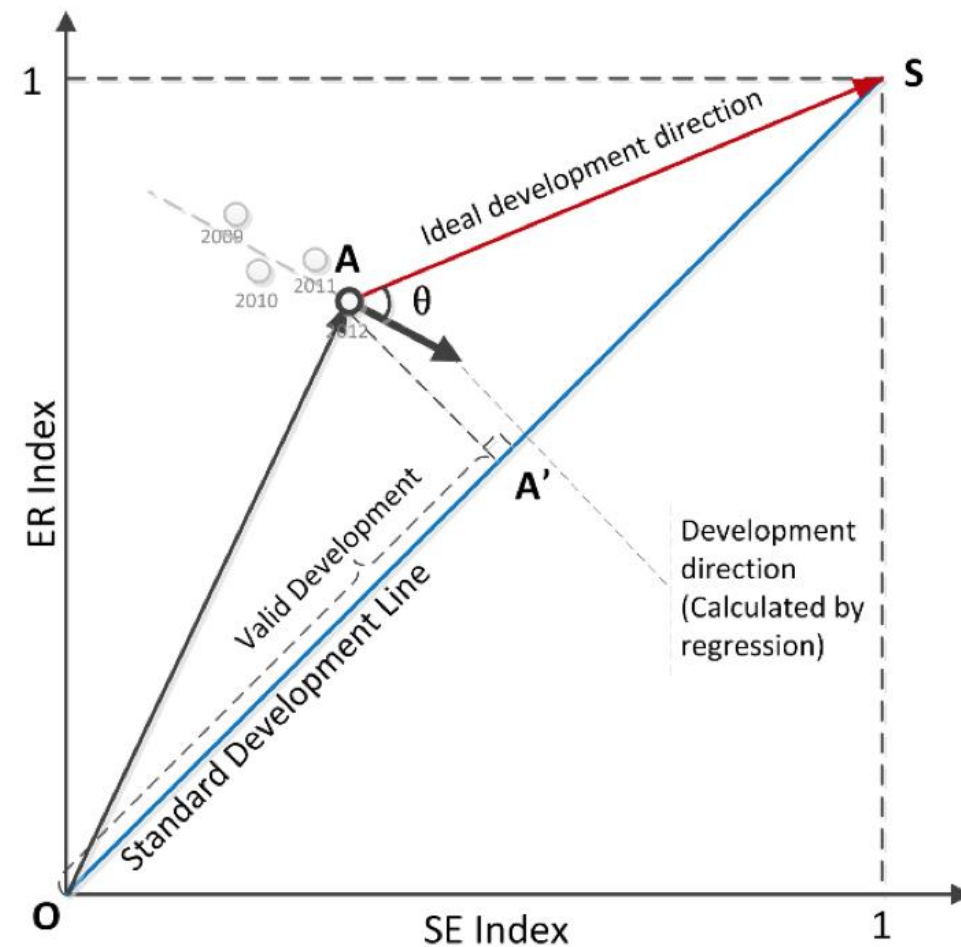
- Harmonious Development Measure
 - The magnitude of the intersection angel between the ideal development direction and the actual development direction of a nation through regression analysis
- Single metric as a result which allows easy relative ranking of nations



From Zhejiang University



- China
- America
- Nepal
- France
- South Africa

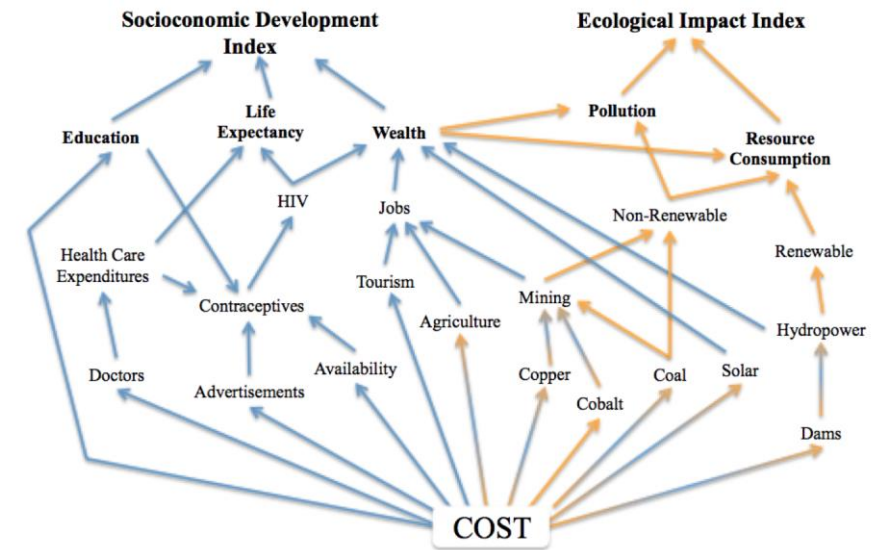
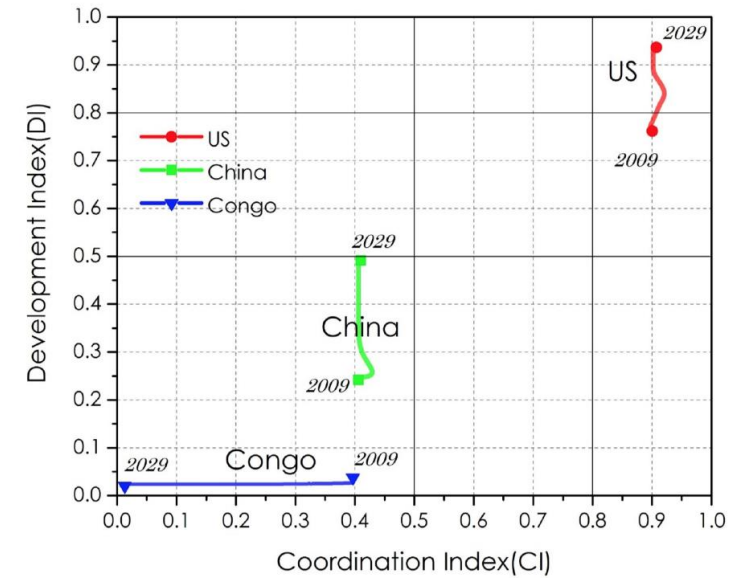


What level of math was needed?

- For each index, they used linear algebra (PCA)
- They used linear trendlines to determine a pattern
- They used trigonometry to define their angle

Some other cool mathematics used!

- Particle Swarm Optimization
- Lanchester Equations
- Trajectory Tracking
- Principle Component Analysis



Conclusions and Discussion

- In these contests, students use a wide range of mathematics
 - Some is advanced and surprising for undergraduates
 - Some is simple and elegant and accessible
 - Good explanations are critical
 - Good visualizations are powerful
- Questions?
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