Leveraging Diversity

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THE DIFFERENCE
HOW THE POWER OF DIVERSITY CREATES BETTER GROUPS, FIRMS, SCHOOLS, AND SOCIETIES
Scott E. Page

DIVERSITY AND COMPLEXITY
Scott E. Page
Outline

Background: Two Inescapable Trends
Identity and Cognitive Diversity
Prediction

Case: Netflix Prize

Problem Solving

Takeaways
Trend 1
Increasing Diversity
Race-Ethnic Profiles by Age Group, 2010

Under 5 years: 51% White, 25% Hispanic, 14% Other, 4% 2+ races
5-17 years: 55% White, 22% Hispanic, 14% Other, 4% 2+ races
18-35 years: 58% White, 20% Hispanic, 13% Other, 5% 2+ races
35-49 years: 64% White, 16% Hispanic, 12% Other, 5% 2+ races
50-64 years: 73% White, 10% Hispanic, 11% Other, 4% 2+ races
65-74 years: 79% White, 7% Hispanic, 9% Other, 4% 2+ races
85+ years: 85% White, 5% Hispanic, 7% Other, 7% 2+ races

Source: Author's analysis of 2010 census data
Countries/Regions Where Multinationals are Growing

- China
- Brazil
- India
- CEE
- Russia
- Indonesia
- Argentina
- Thailand
- Vietnam
Black First-Year Enrollments in U.S. Medical Schools

Source: Association of American Medical Colleges.

Overall racial distribution in anthropology doctorate production, 1995-2007
A TAXONOMY OF TRANSITIONS

racial/ethnic self-identification in Chicago in the year 2000

white ■
black ■
Asian ■
Hispanic ■
other ■

the black lines show Chicago’s official community areas.
each dot represents twenty-five people.
here, Hispanic is exclusive of other categories.
block-level data from the U.S. census.
scale 1:200,000

The same data, aggregated by community area and shown with solid colors.

>80% white
majority white
>80% Hispanic
majority Hispanic
>80% black
majority black
majority Asian
no majority

Chicago
Normative Argument

Equalizing Opportunity.
Addressing past disadvantages.
Pragmatic Advantages

Promoting diversity enlarges the pool.
Trend 2
Changing Nature of Work
Employment by Industry - Percent of Total Workforce

- Trade, Transportation, and Utilities: 20%
- Professional and Business Services: 14%
- Natural Resources and Minerals: 3%
- Government: 15%
- Education and Health Services: 12%
- Other Services: 4%
- Leisure and Hospitality: 9%
- Construction: 7%
- Manufacturing: 9%
- Financial Activities: 6%
- Information: 1%
# First 15 Nobels in Physics: 19 Winners

<table>
<thead>
<tr>
<th>Year</th>
<th>Winners</th>
</tr>
</thead>
<tbody>
<tr>
<td>1901</td>
<td>Wilhelm C. Röntgen</td>
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<tr>
<td>1902</td>
<td>Hendrik A. Lorentz, Pieter Zeeman</td>
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<tr>
<td>1903</td>
<td>Antoine Henri Becquerel, Pierre Curie, Marie Curie</td>
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<tr>
<td>1904</td>
<td>John W. Strutt</td>
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<td>1905</td>
<td>Philipp E. A. von Lenard</td>
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<td>1906</td>
<td>Sir Joseph J. Thomson</td>
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<tr>
<td>1907</td>
<td>Albert A. Michelson</td>
</tr>
<tr>
<td>1908</td>
<td>Gabriel Lippmann</td>
</tr>
<tr>
<td>1909</td>
<td>Carl F. Braun, Guglielmo Marconi</td>
</tr>
<tr>
<td>1910</td>
<td>Johannes D. van der Waals</td>
</tr>
<tr>
<td>1911</td>
<td>Wilhelm Wien</td>
</tr>
<tr>
<td>1912</td>
<td>Nils G. Dalen</td>
</tr>
<tr>
<td>1913</td>
<td>Heike Kamerlingh Onnes</td>
</tr>
<tr>
<td>1914</td>
<td>Max von Laue</td>
</tr>
<tr>
<td>1915</td>
<td>William Bragg</td>
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42
Diverse
+
Group
Rethinking
Want to understand how diversity affects group performance
Diversity

Ability
two heads are better than one
\[ E[\text{SqE}(c)] = B^2 + \frac{1}{n} \text{Var} + \frac{n-1}{n} \text{Cov} \]
Identity and Cognitive Diversity
WESTERNERS AND EAST ASIANS DESCRIBE THIS SCENE IN DIFFERENT WAYS
(SOURCE: THE UNIVERSITY OF MICHIGAN INSTITUTE FOR SOCIAL RESEARCH)
The Ketchup Question
Soda, Pop, or Coke By Region

Map based upon 120,464 Respondants

Map Template courtesy of www.mymaps.com

Respondents through March 1, 2003
Cultural Blinders
Poison Rats
Se pa manje rat
Pwazon Rat

$5
Coumadin.
Prediction
Methods of Divination

Lightning
Smoke and Fire
Flight of Birds
Neighing of Horses
Tea Leaves and Coffee Grounds
Passages of Sacred Texts
Numbers
Guessing

David Orrell, "The Future of Everything.

Model
Diverse Categorizations
Linnean Classification Sort

- Species
- Genus
- Family
- Order
- Class
- Phylum
- Kingdom
Pile Sort
Airstream Sort
Diversity Prediction Theorem

Crowd Error = Average Error - Diversity

\[
(c - \theta)^2 = \frac{1}{n} \sum_{i=1}^{n} (s_i - \theta)^2 - \frac{1}{n} \sum_{i=1}^{n} (s_i - c)^2
\]
The Spherical Cow
The Gateway Cow
Galton’s Steer

Crowd Error = Average Error – Diversity

0.6 = 2,956.0 - 2955.4
Case: Netflix Prize
Outline

Netflix Prize: Background
Predictive Models
   Factor Models
Ensembles of Models
Ensembles of Teams
The Value of Diversity
Netflix Prize

November 2006, Netflix offers a prize of $1 million to anyone who can defeat their Cinematch recommender system by 10% or more.
Some Details

Netflix users rank movies from 1 to 5

Six years of data
Half million users
17,700 movies

Data divided into (training, testing)
Testing Data dived into (probe, quiz, test)
Interesting Asides

Lost in Translation and The Royal Tenenbaums had the highest variance

Shawshank Redemption had the highest rating

Miss Congeniality had the most ratings.
Singular Value Decomposition

Each movie represented by a vector:

\((p_1,p_2,p_3,p_4...p_n)\)

Each person represented by a vector:

\((q_1,q_2,q_3,q_4...q_n)\)

Rating: \(r_{ij} = m_i + a_j + \mathbf{p} \cdot \mathbf{q}\)

Training: choose \(\mathbf{p}, \mathbf{q}\) to minimize

\((\text{actual}_{ij} - r_{ij})^2 + c(\|\mathbf{p}\|^2 + \|\mathbf{q}\|^2)\)
BellKor’s Initial Models

Approximately 50 dimensions, 107 Models

Best Model: 6.8% improvement

Combination of Models: 8.4% improvement
Why Do More Work Better?

\[ \text{SqE}(c) = \text{SqE}(s) - \text{PDiv}(s) \]

\[ (c - \theta)^2 = \frac{1}{n} \sum_{i=1}^{n} (s_i - \theta)^2 - \frac{1}{n} \sum_{i=1}^{n} (s_i - c)^2 \]
BellKor’s Pragmatic Chaos

**More is Better:** Seven person team

**Functional Diversity:** statisticians, machine learning experts and computer scientists

**Identity Diversity:** United States, Australia, Canada and Israel.

Difficult be build a “grand” model (800 variables) but possible to build lots of “huge” models
Ensemble Effects

Best Model 8.4%

Ensemble: 10.1%

Rules: Once someone breaks 10%, then the contest ends in 30 days.
Enter ``The Ensemble’’

23 teams from 30 countries who blended their predictive models who tried in the last moments to defeat BellKor’s Pragmatic Chaos
The Ensemble

“The contest was almost a race to agglomerate as many teams as possible,” said David Weiss, a Ph.D. candidate in computer science at the University of Pennsylvania and a member of the Ensemble.

“The surprise was that the collaborative approach works so well, that trying all the algorithms, coding them up and putting them together far exceeded our expectations.”

New York Times 6/27/09
And The Winner is…

RMSE for The Ensemble: 0.856714
RMSE for Bellkor’s Pragmatic Chaos: 0.856704

By the rules of the competition the scores are rounded to four decimal places so it was a tie.

However, BellKor’s Pragmatic Chaos submitted 20 minutes earlier so they won. (and they had the lower error)
Oh, by the way..

BellKor’s Pragmatic Chaos 10.06%
The Ensemble 10.06%
50/50 Blend 10.19%
Problem Solving
Diverse Perspectives
Page vs de Marchi 3/17/98

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de Marchi
Page vs de Marchi 3/17/98

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de Marchi
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Page

A

2

3

4

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deb Marchi

6

7

8

9

A

2

3

5

4

5

6

7
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Page

4 of Spades
6 of Spades

de Marchi

5 of Spades
6 of Spades
Page vs de Marchi 3/17/98

Page

A♠ 2♠ 3♠

4♠ 6♠ 9♥

de Marchi

7♣ 9♣

5♠ 8♠
Page vs de Marchi 3/17/98

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de Marchi

de Marchi
Page vs de Marchi 3/17/98

Page

4 of Spades
6 of Spades
2 of Spades

de Marchi

5 of Spades
8 of Spades

A Magic Square

8 + 3 + 4 = 15

A + 5 + 9 = 15

6 + 7 + 2 = 15
Play it Again
Diverse Cognitive Models/Heuristics
A Test

• Create a bunch of agents with diverse perspectives and heuristics

• Rank them by their performance on a problem.

• Note: all of the agents must be “smart”
Experiment

Group 1: Best 20 agents
Group 2: Random 20 agents

Have each group work collectively - when one agent gets stuck at a point, another agent tries to find a further improvement. Group stops when no one can find a better solution.
The IQ View

Alpha Group

138  137  139
140  136  132

Diverse Group

121  84  111
75   135  9
The diverse group almost always outperforms the group of the best by a substantial margin.

See Lu Hong and Scott Page

The Toolbox View

Alpha Group

- ABC
- ACD
- BDE
- BCD
- ADE
- BCD

Diverse Group

- AHK
- FD
- AEG
- EZ
- BCD
- IL
two heads are better than one
What Must be True?

Calculus Condition: *Problem solvers must all be smart-
-we must be able to list their local optima*

Diversity Condition: *Problem solvers must have
diverse heuristics and perspectives*

Hard Problem Condition: *Problem itself must be difficult*
Realizing Diversity’s Benefits
Eureka!
Group Accuracy & Perceived Effectiveness
Phillips, Liljenquist, & Neale, 2009

Controls for individual performance & how well group members know one another.
Group Objective Accuracy vs Confidence in Decision

% Groups Accurate

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<thead>
<tr>
<th></th>
<th>Homogeneous</th>
<th>Diverse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidence in Decision</td>
<td>60</td>
<td>78</td>
</tr>
</tbody>
</table>

Homogeneous | Diverse

Homogeneous | Diverse
The Prepared Mind
The Prepared Mind Community