eHarmony
Maximizing the Probability of Love

Heart image is in the public domain. Source: Wikimedia Commons.
About eHarmony

• Goal: take a scientific approach to love and marriage and offer it to the masses through an online dating website focused on long term relationships

• Successful at matchmaking
  • Nearly 4% of US marriages in 2012 are a result of eHarmony

• Successful business
  • Has generated over $1 billion in cumulative revenue
The eHarmony Difference

• Unlike other online dating websites, eHarmony does not have users browse others’ profiles

• Instead, eHarmony computes a compatibility score between two people and uses optimization algorithms to determine their users’ best matches

Image of candy hearts is in the public domain.
Source: Wikimedia Commons.
eHarmony’s Compatibility Score

- Based on 29 different “dimensions of personality” including character, emotions, values, traits, etc.
- Assessed through a 436 question questionnaire
- Matches must meet >25/29 compatibility areas
Dr. Neil Clark Warren

- Clinical psychologist who counseled couples and began to see that many marriages ended in divorce because couples were not initially compatible

Research → Business

• In 1997, Warren began an extensive research project interviewing 5000+ couples across the US, which became the basis of eHarmony’s compatibility profile

• [www.eHarmony.com](http://www.eHarmony.com) went live in 2000

• Interested users may fill out the compatibility quiz, but in order to see matches, members must pay a membership fee to eHarmony
eHarmony Stands Out From the Crowd

- eHarmony was not the first online dating website and faced serious competition

- Key difference from other dating websites: takes a quantitative optimization approach to matchmaking, rather than letting users browse
Integer Optimization Example

• Suppose we have three men and three women
• Compatibility scores between 1 and 5 for all pairs

15.071x – eHarmony: Maximizing the Probability of Love

Woman and man icons on this and the following pages are in the public domain. Source: Openclipart.
Integer Optimization Example

- How should we match pairs together to maximize compatibility?

![Diagram showing the matching process with numbers 1 to 5 indicating compatibility scores for each match.]
Data and Decision Variables

- Decision variables: Let $x_{ij}$ be a binary variable taking value 1 if we match user $i$ and user $j$ together and value 0 otherwise.
- Data: Let $w_{ij}$ be the compatibility score between user $i$ and $j$. 

\[
\begin{array}{ccc}
& 1 & \\
5 & 3 & 4 \\
& 2 & \\
2 & 2 & 5 \\
& 3 & \\
1 & & \\
\end{array}
\]
Objective Function

- Maximize compatibility between matches:
  \[ \max w_{11}x_{11} + w_{12}x_{12} + w_{13}x_{13} + w_{21}x_{21} + \ldots + w_{33}x_{33} \]
Constraints

- Match each man to exactly one woman:

\[ x_{11} + x_{12} + x_{13} = 1 \]
Constraints

- Similarly, match each woman to exactly one man:
  \[ x_{11} + x_{21} + x_{31} = 1 \]
Maximize $w_{11}x_{11} + w_{12}x_{12} + w_{13}x_{13} + w_{21}x_{21} + \ldots + w_{33}x_{33}$

Subject to:

- $x_{11} + x_{12} + x_{13} = 1$
- $x_{21} + x_{22} + x_{23} = 1$
- $x_{31} + x_{32} + x_{33} = 1$
- $x_{11} + x_{21} + x_{31} = 1$
- $x_{12} + x_{22} + x_{32} = 1$
- $x_{13} + x_{23} + x_{33} = 1$

$x_{11}, x_{21}, x_{31}, x_{12}, x_{22}, x_{32}, x_{13}, x_{23}, x_{33}$ are binary

Match every man with exactly one woman

Match every woman with exactly one man
Extend to Multiple Matches

- Show woman 1 her top two male matches:
  \[ x_{11} + x_{21} + x_{31} = 2 \]
Compatibility Scores

• In the optimization problem, we assumed the compatibility scores were data that we could input directly into the optimization model.

• But where do these scores come from?

• “Opposites attract, then they attack”
  – Neil Clark Warren

• eHarmony’s compatibility match score is based on similarity between users’ answers to the questionnaire.
Predictive Model

- Public data set from eHarmony containing features for ~275,000 users and binary compatibility results from an interaction suggested by eHarmony

- Feature names and exact values are masked to protect users’ privacy

- Try logistic regression on pairs of users’ differences to predict compatibility
Reduce the Size of the Problem

- Filtered the data to include only users in the Boston area who had compatibility scores listed in the dataset
- Computed absolute difference in features for these 1475 pairs
- Trained a logistic regression model on these differences
Predicting Compatibility is Hard!

- Model AUC = 0.685

- If we use a low threshold we will predict more false positives but also get more true positives

- Classification matrix for threshold = 0.2:

<table>
<thead>
<tr>
<th>Act\Pred</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1030</td>
<td>227</td>
</tr>
<tr>
<td>1</td>
<td>126</td>
<td>92</td>
</tr>
</tbody>
</table>
Other Potential Techniques

• Trees
  • Especially useful for predicting compatibility if there are nonlinear relationships between variables

• Clustering
  • User segmentation

• Text Analytics
  • Analyze the text of users’ profiles

• And much more…
How Successful is eHarmony?

• By 2004, eHarmony had made over $100 million in sales.
• In 2005, 90 eHarmony members married every day
• In 2007, 236 eHarmony members married every day
• In 2009, 542 eHarmony members married every day
eHarmony Maintains its Edge

- 14% of the US online dating market.

- The only competitor with a larger portion is Match.com with 24%.

- Nearly 4% of US marriages in 2012 are a result of eHarmony.

- eHarmony has successfully leveraged the power of analytics to create a successful and thriving business.