Simulating Crossword Lottery Tickets

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What is a crossword scratch ticket?

To win, players scratch the “YOUR LETTERS” box to reveal 20 letters of the alphabet.

Afterwards, players scratch off where they see those letters in the crossword.

If 3+ words are fully scratched off, the player wins the prize corresponding to the “PRIZE GRID”.

Requirements/constraints

- The average puzzle has 22 words and has a letter bank of 20 letters
  - The words can only go horizontally and vertically
- Each puzzle is on a 11 x 11 grid
  - No words longer than 11 characters; no words shorter than 3 characters
- All the different letters in each word have to be in the letter box for the word to be "completed"
- 3 words have to be completed to break even; 4 words have to be completed to make a profit

Declaring the elements of a Given Scratch Ticket

The program reads the words from a given puzzle from a csv file created on Microsoft Excel and puts them in a 22 x 26 matrix.

The variable k in the program is used to choose which puzzle.

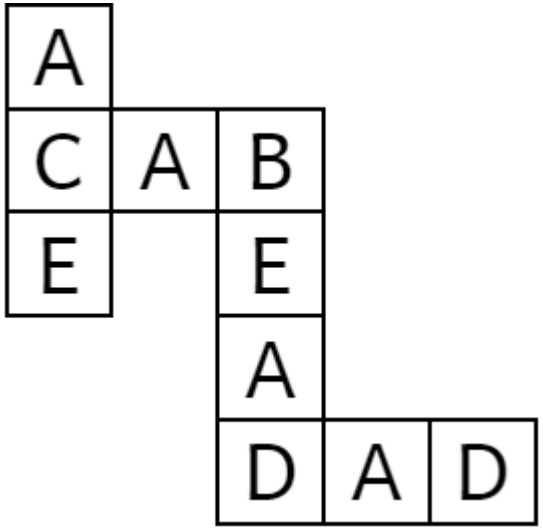
Word Number	1	2	3	4	5
PuzzleOne	oval	edit	town	farm	exist
PuzzleTwo	they	smog	act	near	unit
PuzzleThree	guide	city	versatile	sharp	mop

• • •

21	22
end	dish
oyster	overcoat
pie	duel

Small Scale Visual Example

- Words:
  - Ace
  - Cab
  - Bead
  - Dad
- Letter bank:
  - Contains 5 letters from A, B, C, D, E, and F



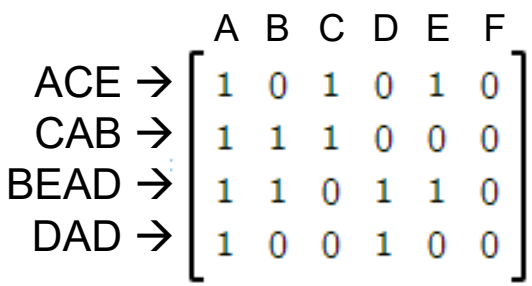
Matrix 1: Reading the words into the computer

This 22 x 26 matrix puts 1's in the columns that correspond with the letters in each word.

Column 1 represents A
Column 2 represents B

Column 26 represents Z

Visual Example

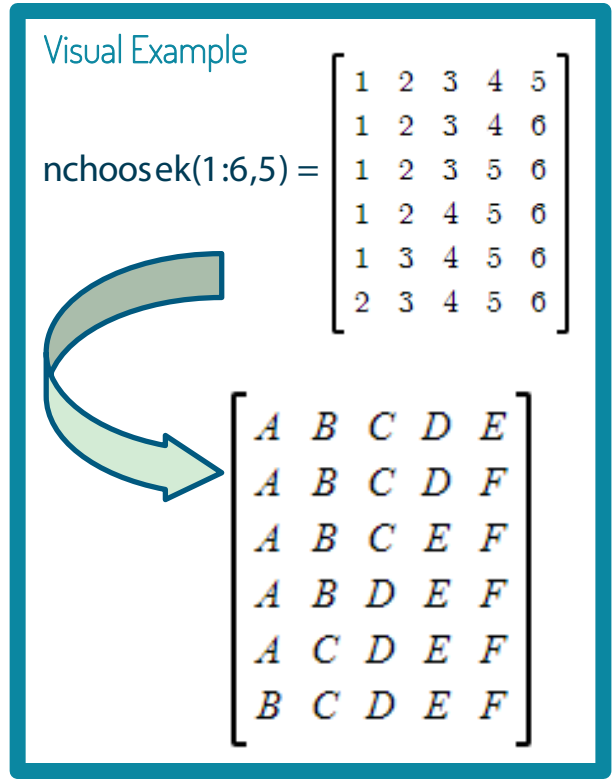


Generating All the Possible Combinations of Letter Banks

To find out how many possible 20 letter combinations there are in the alphabet, the code uses:

nchoosek(1:26,20)

This shows that there are 230,230 possible letter banks.



Matrix 2: Counting the number of completed words

The program then generates a second matrix where column 1 labels each possible letter bank and column 2 is filled with the number of words completed in each different letter bank.

Visual Example

$$\text{Matrix 2} = \begin{bmatrix} 1 & 4 \\ 2 & 2 \\ 3 & 2 \\ 4 & 2 \\ 5 & 2 \\ 6 & 0 \end{bmatrix}$$

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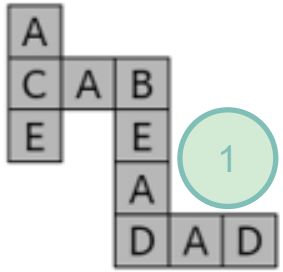
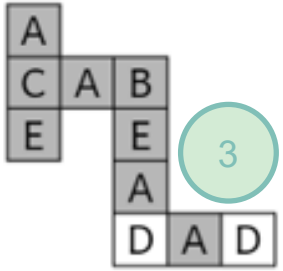
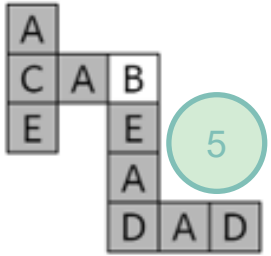
$$\begin{bmatrix} 1 & 4 \\ 2 & 2 \\ 3 & 2 \\ 4 & 2 \\ 5 & 2 \\ 6 & 0 \end{bmatrix}$$



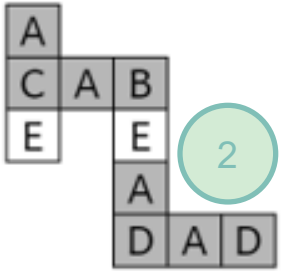
A, B, C, D, E



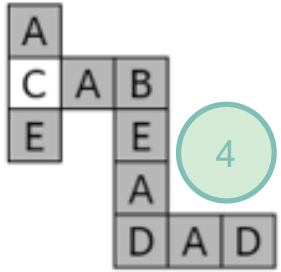
A, B, C, E, F



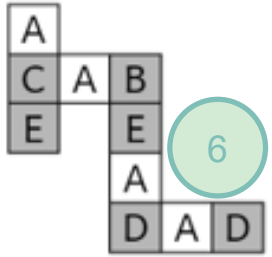
A, C, D, E, F



A, B, C, D, F



A, B, D, E, F



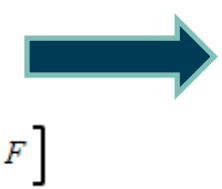
B, C, D, E, F

How was Matrix 2 programmed?

Example:

4

$$\begin{bmatrix} A & B & D & E & F \end{bmatrix}$$



$$\begin{array}{c} \\ \text{ACE} \rightarrow \\ \text{CAB} \rightarrow \\ \text{BEAD} \rightarrow \\ \text{DAD} \rightarrow \end{array} \begin{array}{c} \begin{matrix} A & B & D & E & F \end{matrix} \\ \begin{bmatrix} 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 \end{bmatrix} \end{array}$$

Sum up the rows

$$\begin{bmatrix} 2 \\ 2 \\ 4 \\ 2 \end{bmatrix}$$

S_1

$$\begin{array}{c} \\ \text{ACE} \rightarrow \\ \text{CAB} \rightarrow \\ \text{BEAD} \rightarrow \\ \text{DAD} \rightarrow \end{array} \begin{array}{c} \begin{matrix} A & B & C & D & E & F \end{matrix} \\ \begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 \end{bmatrix} \end{array}$$

Recall matrix 1

Sum up the rows

$$\begin{bmatrix} 3 \\ 3 \\ 4 \\ 2 \end{bmatrix}$$

S_2

Compare S_1 & S_2

$$\begin{bmatrix} 0 \\ 0 \\ 1 \\ 1 \end{bmatrix}$$

Zero: S_1 & S_2 are different
One: S_1 & S_2 are equal

The sum of the final matrix is 2. Therefore, this specific letter bank only has 2 words completed.

Matrix 3: Calculating winnings

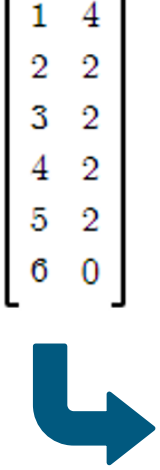
1: Yes
0: No

This 230,230 x 10 matrix puts a 1 in the column associated with the prize amount corresponding with all possible letter banks

Column	Prize
1	lists 1-230,230
2	< 3 words met; loss
3	$3 win
4	$6 win
5	$9 win
6	$20 win
7	$50 win
8	$100 win
9	$1,000 win
10	$50,000 win

Matrix 2 =

$$\begin{bmatrix} 1 & 4 \\ 2 & 2 \\ 3 & 2 \\ 4 & 2 \\ 5 & 2 \\ 6 & 0 \end{bmatrix}$$



loss $6 win

$$\begin{bmatrix} 1 & 0 & 0 & 1 \\ 2 & 1 & 0 & 0 \\ 3 & 1 & 0 & 0 \\ 4 & 1 & 0 & 0 \\ 5 & 1 & 0 & 0 \\ 6 & 1 & 0 & 0 \end{bmatrix}$$

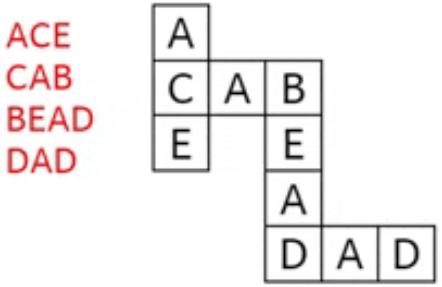
$3 win

Checking Winners

Users can input their words and letter bank to check the prize amount won.

To do so, the program takes in the letter bank, identifies which row in Matrix 3 it corresponds to, and returns the winning amount.

ACE
CAB
BEAD
DAD



Note: this does not yet account for the bonus box winnings

Probabilities

Calculated probabilities of winning example:

Prize	Probability
Loss	11.30%
$3	7.62%
$6	10.17%
$9	12.00%
$20	12.24%
$50	11.54%
$100	9.05%
$1,000	6.84%
$50,000	19.25%

Published probabilities of winning:

Prize	Probability
Loss	73.474801%
$3	11.590014%
$6	10.548809%
$9	2.553669%
$20	1.552280%
$50	0.000878%
$100	0.000568%
$1,000	0.000064%
$50,000	0.000002%

Adapted from NHLottery

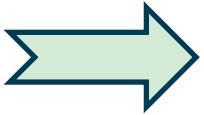
Conclusion

There is a significant discrepancy between the calculated and published probabilities.

The letter banks are not randomly selected.

Generating Random Letter Bank

This function takes in the given words and the desired completed words and returns a random letter bank with the desired number of completed words.



It simulates a way in which the NH lottery system may generate the tickets since the probabilities show that the letter boxes are not randomly generated.

Further Research

Incorporating the red lines and bonus multiplier for "Red Line" version

Looking into how many are sold yearly and if they are in other states

Incorporating the bonus box prize amount

Connecting an online word database to generate the 11 x 11 grid with 22 words

Thank you for your time!

References

"$3 Money Puzzle Flower Power!" *Money Puzzle Flower Power | New Hampshire Lottery* New Hampshire Lottery, www.nhlottery.com/Games/Scratch-Tickets/$3/Money-Puzzle-Flower-Power.