

THUGS & BOWMEN

A new twist to the ancient game of Roshambo

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1. Roshambo

Unless there has recently been a cataclysm and the global population has diminished to less than a few thousand, right now, chances are that somewhere in the world, two people are facing off. In a moment, at an agreed upon point in time, possibly after a ritual chant, they'll shape their hands into a rock by holding a fist, a pair of scissors by extending only the middle and index fingers, or a sheet of paper by extending all the fingers along the plane of the palm. The winner is decided according to the mnemonic: rock crushes scissors, which cut paper, which envelops rock.

That almost everyone on Earth knows how to play Roshambo is perhaps deeply rooted in human psychology: no one likes the idea of an invincible foe, nor of being vulnerable to attacks from all. If one must needs be conquered by an individual, one may at least find personal solace in the ability to conquer one capable of conquering that individual. This aspect is perhaps more directly explored in an ancient Japanese version of the game in which players choose between a mother, a chieftain or a tiger: the chieftain can kill the tiger with his cunning, but is bound by duty to the will of his mother, who, in turn, is easy prey to the tiger.

The fact that some children in every playground are able to significantly beat others over an extended period, and that algorithms can be developed that perform well in Roshambo programming competitions¹ suggests that the game isn't entirely determined by luck. A completely random choice would indeed be impossible to beat in the long run, but it is very difficult to produce such a thing – whatever it may mean; and what remains is vulnerable to attack by pattern analysing algorithms.

Roshambo is not only used to settle little disputes and squabbles in the playground. Takashi Hashiyama, for example, the president of a Japanese electronics company, decided to use a game of Roshambo to determine whether the Christie's or the Southby's auction house would sell the company's art collection, valued at over twenty million dollars, and including works by

Cézanne, Picasso and van Gogh².

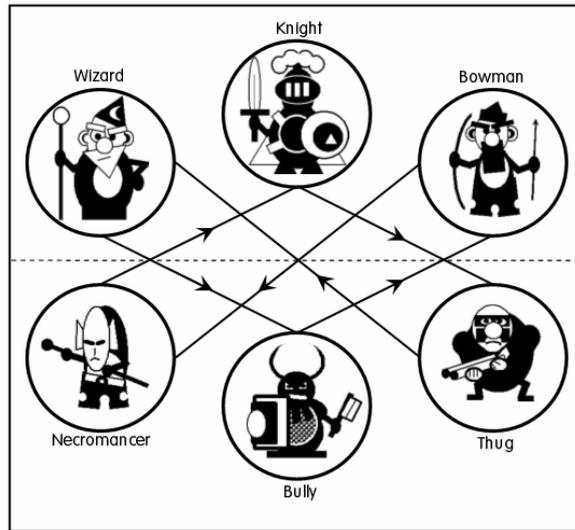
Roshambo has also been of importance to Biologists developing models to explain how certain phenotypes may continue to exist in populations although there also exist one or more other phenotypes that seem to be evolutionarily superior, and that might have been expected to drive the less competitive traits to extinction.

For example, in *Escherichia coli* populations, there exist three strains: colicin producers (**C**), colicin resistant (**R**) and colicin sensitive (**S**)³. Colicins are antibiotics that are toxic to *E. coli* unless they produce an immunity protein. The **C** strain produces both the toxin and the immunity protein (so that it doesn't kill itself off), both of which are energetically expensive. The **R** strain produces the immunity protein, but not the toxin. It is thus immune to the toxin, but has more energy than the **C** strain to expend on growth and division, and thus will displace it. The **S** strain produces neither the toxin nor the immunity protein, and hence has even more energy to devote to growth and division and can hence displace the **R** strain; however, since it does not produce the immunity protein, it is vulnerable to being killed off by the **C** strain. Rock, paper, scissors.

Similar games have been discovered in eukaryote populations too. Three morphs, distinguishable both in appearance and behaviour, exist in populations of the side-blotched lizard, *Uta stansburiana*⁴. Dominant, orange throated males defend large territories with many females. This strategy allows them to out-compete less dominant blue throated males who tend to defend small territories large enough only for one female; but leaves them susceptible to female-mimicking yellow-striped males who don't defend territory at all, but whose strategy it is to sneak into the territories of other males and copulate with the females therein. The blue-throats, however, since their attention is spread out over a small territory, effectively defend their females from the yellow-stripes. Again: rock, paper, scissors. (Let's ignore ostensibly analogous strategies that exist in human populations.)

2. Thugs and Bowmen

Thugs and Bowmen adds an interesting twist to Roshambo: it is a game of Good vs. Evil. For Good stand the **Wizard** (paper), the **Knight** (rock) and the **Bowman** (scissors); for Evil, the **Necromancer** (paper), the **Bully** (rock) and the **Thug** (scissors). The arrows in the figure to the right represent the relation 'defeats'. A game is played by one player acting the aggressor, attacking a permutation with repetition allowed of the other player's pieces with one of his own. The aggressor is blind, but his permutation is allowed to evolve with time. The player being attacked cannot alter his original permutation, and must respond to each attack by informing the blind aggressor how many of his (the aggressor's) pieces won and lost against the respective defensive pieces. The aggressor, though not told *which* of his pieces won or lost, may nevertheless use these clues to make an adjustment to the next attacking permutation. The object is for the aggressor to win completely in the least number of moves.



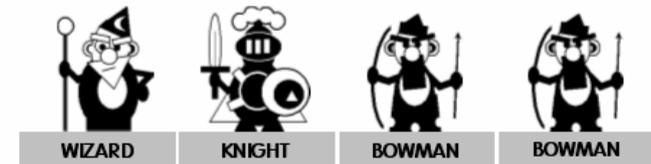
victories and one defeat. Evil is then allowed to attack again. If he thinks about it, he'll realise that two of his pieces should remain as they are, since there were two victories; and of the other two, one should change to the power (*i.e.*, rock, paper or scissors) that would defeat it – since there was one draw, and the remaining piece should

change to the power that loses to it and that hence beats the power the piece just lost to, since there was one defeat. The next attack would not, for example, be

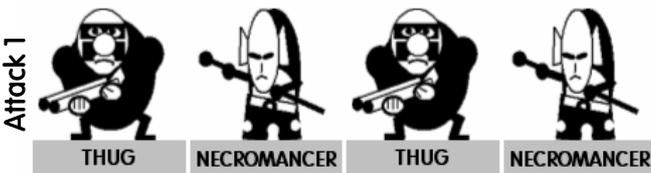
change to the power that loses to it and that hence beats the power the piece just lost to, since there was one defeat. The next attack would not, for example, be



but perhaps



Evil, from whom this permutation is concealed, attacks with a permutation of his own men:



Good responds by giving the clue (2,1), signifying two

In this case, the player assumed the middle two pieces of **Attack 1** were victorious, that the remaining Thug (position 1) was defeated (by a Knight who would lose to a Necromancer) and that the remaining Necromancer (position 4) drew (with a Wizard who would lose to a Thug).

The clue that the aggressor would then receive is (1,0), which could be used in conjunction with the previous clue to improve the probability of success for the next attack.

3. Comparison of Thugs and Bowmen to other combinatorial optimization problems

Thugs and Bowmen is actually very similar to the old game *Bulls and Cows* or, more recently, *Mastermind*⁵. In *Bulls and Cows*, one player sets up a secret number made up of several digits. The other player tries to guess this number. After each guess, the number of correct digits in the correct position (bulls – or black marks) and the number of correct digits but in the wrong position (cows – or white marks) are given. *Mastermind* is virtually identical except that colours are used instead of numerical digits, and repetitions are allowed, which is traditionally not the case with *Bulls and Cows*.

Thugs and Bowmen is significantly different from these two games, however, in that when clues are assigned, each piece of the attacking combination is only compared by the defensive player to the piece in the respective position of the

hidden combination, and there is no lateral comparison with other pieces as exists in *Bulls and Cows* and *Mastermind*. In this respect, *Thugs and Bowmen* is similar to another game called *The Five Vowels*⁶, in which one player must try to guess a permutation of vowels created by the other player, who returns how many of the vowels guessed were too high (according to alphabet position) and how many were too low. *Thugs and Bowmen* is significantly different from *The Five Vowels* in that all the pieces of the former are equal, whereas **A**, for example, has four vowels higher (**E**, **I**, **O** and **U**) and none lower, compared with **O**, for example, with three vowels lower (**A**, **E** and **I**) and one higher (**U**). For this reason, a first guess is just as good as any other in *Thugs and Bowmen*, but some first guesses are more likely to receive clues that convey more information in *The Five Vowels*.

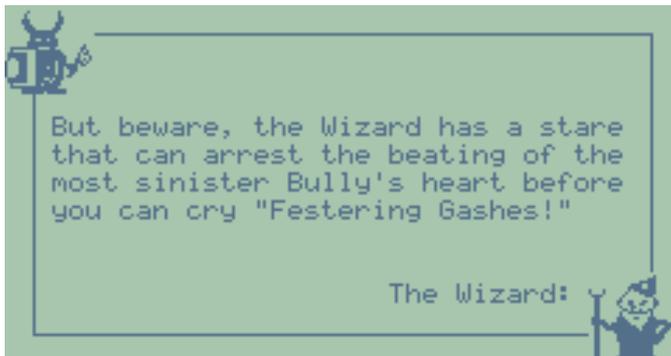
4. An algorithm to solve a Thugs and Bowmen problem

The similarity between *Thugs and Bowmen* and *Mastermind* is sufficiently great that it may be solved in an a very similar way to that described in an old BASIC computer game book I had as a child⁷, and that I believe was first described by Donald Knuth⁷. The version of *Thugs and Bowmen* for the TI-92/V200 graphical display calculator that accompanies this essay solves the problem using the following steps:

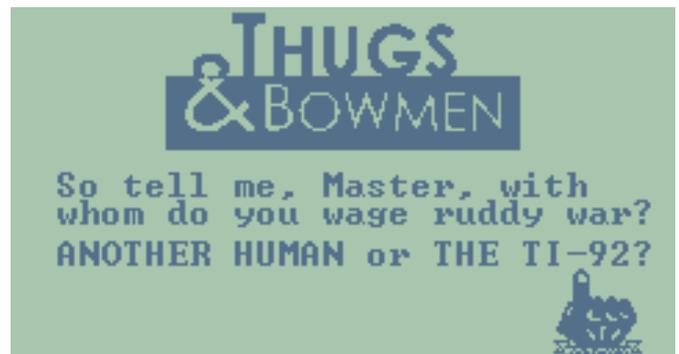
- A. Set up an array of Boolean variables, one variable for each permutation possible, numbered from 0 to $3^n - 1$, where n is the number of positions to be used (in the previous examples, 4). This array is used to mark a permutation as being eligible or not for the next guess. Since each variable can only have one of two values (eligible or not), $3^n/8 + 1$ (in our case 11) bytes are sufficient to allow the calculator to recall which permutations are still eligible. To check if permutation number x (the way the permutations are numbered is explained in step B) is eligible, the value of bit number $x \bmod 8$ of byte number $x \div 8$ needs to be checked.
- B. Let the pieces rock, paper and scissors represent the integer values 0, 1 and 2 respectively. Now each permutation may be assigned a unique number, namely, the value of the base-3 number represented by a combination. For example, the combination rock (0) - paper(1) - scissors (2) - rock (0) could be represented by $(0120)_3 = (15)_{10}$ and hence be the fifteenth permutation (rock-rock-rock-rock would be the zeroth permutation).
- C. Guess a random permutation from the set of permutations marked eligible.
- D. Receive clues **v** and **d** from opponent for number of victories and defeats respectively. Go through each Boolean variable in the array, and if it is not already marked ineligible, attack the respective permutation with the permutation just guessed. Assign yourself clues **v₀** and **d₀** for this attack and compare the values with **v** and **d**. If the permutation is impossible, mark it ineligible.
- E. Go back to step C until four victories have been awarded.

Screenshots

Following are some screenshots. The programme was written in C using the TIGCC IDE (<http://tigcc.ticalc.org/>) and tested using Virtual-TI available at the Technoplaza website at <http://www.technoplaza.net/>.



Some mnemonics are given at the beginning of the game.



Play against someone else or the calculator.



The calculator attacks and you input the clues...



... and then change roles. The calculator will let you know if you make a mistake with your logic.



And also if you've made a mistake in assigning clues!



References and comments

1. **International Roshambo Programming Competition**
Details and results posted at University of Alberta Computer Science pages:
<http://www.cs.ualberta.ca/~darse/rsbpc.html>
2. VOGEL, C. *Rock, Paper, Payoff: Child's Play Wins Auction House an Art Sale*, New York Times (29 April 2005)
3. KIRKUP, B. C. & RILEY, M. A. *Antibiotic-mediated antagonism leads to a bacterial game of rock-paper-scissors in vivo* (2004); Nature 428: 412-414
4. SMITH, J. M. *Evolution: the games lizards play* (1996); Nature 380: 198-199
Reporting on an article by SINERVO, B. & LIVELY, C. M. Nature 380: 240-243
5. **Mastermind®** by Invicta Plastics Ltd.
Invented by Mordechai Meirovitz
6. **The Five Vowels**
I thought that I had invented this twist to *Bulls and Cows* in 2003, and even developed the algorithm to solve a *Five Vowels* type problem. I have since then, however, discovered that someone else suggested an equivalent twist (using digits instead of vowels, though) in an article written in the late seventies, if I remember correctly. Unfortunately, I haven't been able to find the article again, nor the name of the person who first made the suggestion. My essay is incomplete without this reference.
7. **AHL, D. (Editor) BASIC Computer Games (1978); Workman Publishers**
A collection of BASIC program listings that had appeared in the magazine *Creative Computing*. The full text has been archived at <http://www.atariarchives.org/basicgames/>
The book features a description of an algorithm that can be used to solve Mastermind problems. Although it doesn't mention who first came up with the algorithm, I believe it was first described in
KNUTH, D. E. The Computer as Master Mind (1976-77); Journal of Recreational Mathematics, 9: 1-6.
though I haven't seen the article myself.