A bounds-driven analysis of "Skull and Roses" cards game

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About the Game

Skull & Roses is a card game based on bluff and composed of a large number of short mini-games.

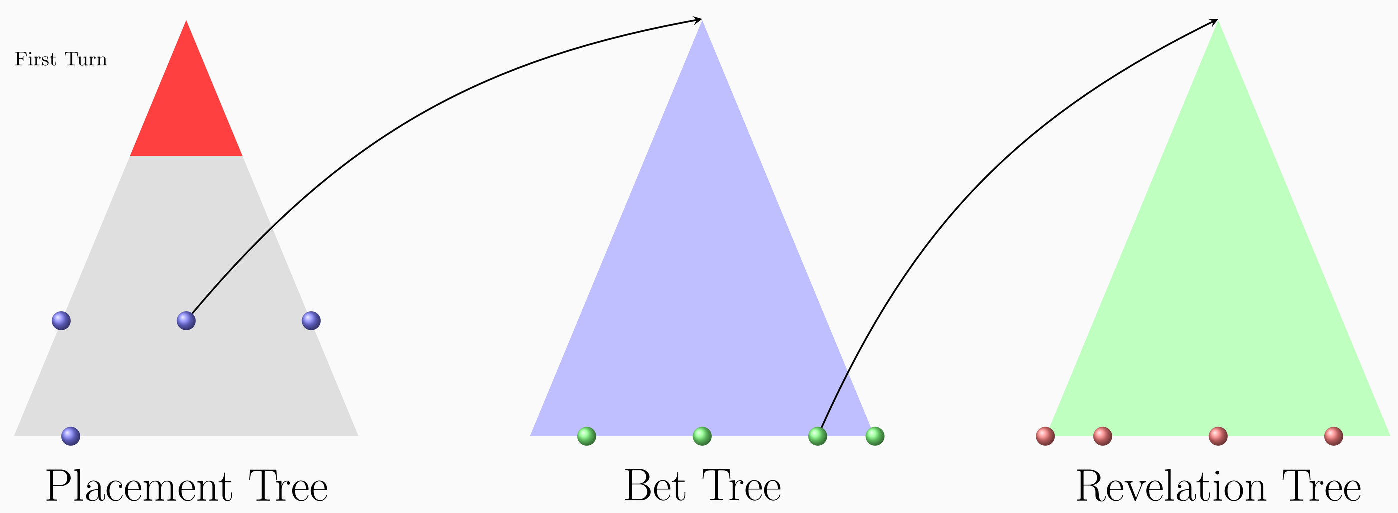
It was created by Hervé Marly, illustrated by Rose Kipik, and edited by *lui-même* in 2010. The game received the international price of as d'or, jeu de l'année, Cannes 2011.

Relevant properties

- Four parameters: P players, S cards of skull, R cards of rose, W number of wins required; (with $3 \leqslant P \leqslant 12$ players, $S = 1$ skull, $R = 3$ roses and $W = 2$ wins – in the *Skull & Roses RED*).
- Compared to Go and Shogi, this game learning curve is much shorter.
- The game has three game stages with totally differentiated gameplays, but decision on each one affect the progress on the others.
- Hard game with partial information.
- It took Hervé Marly 15 years to balance the game.

Different stages

A game is composed of rounds, each of them is divided into three stages. A player win if he has W wins and is disqualified if he has no card left.



Placement: Players will consecutively play a card till one of them bet a number of card b between 1 and c, the number of cards played. Bet cannot occur before everyone play at least one card. Someone who cannot play a card has to bet.

Bet: Current player can either bet strictly more than b or pass. It goes on till everyone pass or c is reached. A player that have passed cannot bet anymore.

Revelation: The player who previously won the challenge will try to reveal the number of cards he bet on. If he reveal a skull, the round stops and he loose one of his cards. Otherwise he wins a point. He first needs to reveal all of his cards. Then, he reveals one of the top card of the other players deck, and repeat it as necessary.

The skull and the three roses cards from the "Skull & Roses" card game designed by Hervé Marly and ilustrated by Rose Kipik

State space analysis

Our results are obtain by studying separately the different stages.

$$
\begin{aligned}
&\text{Round Variables} &&: P\left[(S+1)(R+1)(W+1)\right]^P \\
&\text{Placement Variables} &&: (R+S)\left[2\binom{S+R}{S}\right]^P \\
&\text{Betting Variables} &&: P(R+S)2^P \\
&\text{Revelation Variables} &&: (R+2)+(R+1)^{P-1}
\end{aligned}
$$

Combining them to form the global upper-bound, we get:

$$
\text{State Space Size} \leq P^2(R+S)^2 \cdot \left[R+2+(R+1)^{P-1}\right] \times \left[4(S+1)^2(R+1)(W+1)\binom{S+R}{S}\right]^P .
$$

Upper-bounds

The results on the search tree size came in a similar way than for the state space size.

(P,S,R,W)	State-space size	Tree size
$(2,1,3,2)$	10^{9}	10^{66}
$(3,1,3,2)$	10^{13}	10^{226}
$(4,1,3,2)$	10^{16}	10^{506}
$(5,1,3,2)$	10^{20}	10^{919}
$(6,1,3,2)$	10^{24}	10^{1475}
$(7,1,3,2)$	10^{27}	10^{2181}
$(8,1,3,2)$	10^{31}	10^{3043}
$(9,1,3,2)$	10^{34}	10^{4068}
$(10,1,3,2)$	10^{38}	10^{5262}
$(11,1,3,2)$	10^{42}	10^{6628}
$(12,1,3,2)$	10^{45}	10^{8169}

Comparison with other games

Game	Game length	Branching factor	State-space	Game Tree
Connect Four [1, 5]	36	4	10^{13}	10^{21}
$S\&R(3,1,3,2)$	63	2	10^{13}	10^{226}
Backgammon [4]	55	250	10^{20}	10^{144}
$S\&R(6,1,3,2)$	434	16	10^{24}	10^{1475}
$S\&R(9,1,3,2)$	1304	43	10^{34}	10^{4068}
$S\&R(12,1,3,2)$	2858	149	10^{45}	10^{8169}
Chess [3]	80	35	10^{47}	10^{123}
Shogi [2, 7]	115	92	10^{71}	10^{226}
Go [1, 6]	150	250	10^{171}	10^{360}

Contribution

- Formalization of the rules and first analysis of *Skull & Roses* .
- Upper-bounds for the *space-tree size* and the *search tree size.*
- Simulation to compute the average *branching factor* and *game length.*

Future Work

- Develop a Monte-Carlo based AI.
- Specific cases when some variables are set to be fixed. Specifically, we are improving our *search tree size* upper bound for the case when $S = 1$, $R = 3$, $W = 2$ as in *Skull & Roses RED.*
- Look for further evidences that developing a competitive AI strategy for *Skull & Roses* is difficult.

References

[1] V. L. Allis. *Searching for solutions in games and artficial intelligence.* PhD thesis, University of Limburg, Maastricht, 1994.
[2] H. Iida, M. Sakuta, and J. Rollason. Computer shogi. *Artificial Intelligence*, 134(1-2):121–144, 2002.
[3] C. E. Shannon. Programming a computer for playing chess. *Philos. Mag. (7)*, 41(314):256–275, mar 1950.
[4] G. Tesauro. Practical issues in temporal difference learning. In *Machine Learning*, pages 257–277, 1992.
[5] J. Tromp. John's connect four playground.
[6] J. Tromp and G. Farneback. Combinatorics of go. In *Proceedings of 5th International Conference on Computer and Games*, Torino, Italy, May 2006.
[7] S.-J. Yen, J.-C. Chen, T.-N. Yang, and S.-C. Hsu. Computer chinese chess. *ICGA Journal*, 27(1):3–18, 2004.

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