

Supplementary Materials: Quantum *Go* Machine

A Complete Kifu

Some readers may be interested in the game of quantum *Go*, and want to play it with a quick start. So we provide a complete Kifu in Kifu.dat (Can be opened with any text editor). Hundreds of moves in the Kifu will make readers familiar with the rules of the game.

In addition to the game states, the number of stones and the average information sets size are also given in each move. The average number of white quantum stones at move N (when N is an even number) is $Q_{avg}^N = (\sum_{i=0}^{\frac{N}{2}} Q_{2i}) / (\frac{N}{2} + 1)$. The average number of black quantum stones at move N (when N is an odd number) is $Q_{avg}^N = (\sum_{i=1}^{\frac{N+1}{2}} Q_{2i-1}) / (\frac{N+1}{2})$. The average information sets size is: $S_{avg.info\ set}^N = \binom{2}{1}^{Q_{avg}^{N-1}}$. In the following, We use some game states to illustrate how to calculate these parameters by using these formulas.

The first four moves of a game played by the bots are shown in Fig.S1. There is no stone on the board at the start ($Q_{avg}^0 = 0$), so $S_{avg.info\ set}^1 = \binom{2}{1}^0 = 1$ for the black player (as the black player first to play). After move 1, there is one black quantum stone on the board ($Q_{avg}^1 = 1$), so $S_{avg.info\ set}^2 = 2$ for the white player who is next to play. After move 2, there is one white quantum stone on board. So the average number of white quantum stones on board is $(0 + 1)/2 = 0.5$, and $S_{avg.info\ set}^3 = 1.4$ for the black player in move 3. In the same way, we can calculate that $S_{avg.info\ set}^4 = 2.8$ and $S_{avg.info\ set}^5 = 2$.

In each turn, one quantum stone will be added to the board if no player passes, while the number of quantum stones will reduce when the collapse measurement takes place. In Fig.S2a, white10 is placed on C16 and L10 which causes the collapse measurement. After the measurement, there remains 4 white quantum stones on board, so $Q_{avg}^{10} = (\sum_{i=0}^5 Q_{2i}) / (5 + 1) = (4 + \sum_{n=0}^4 n) / 6 = \frac{7}{3}$ and $S_{avg.info\ set}^{11} = \binom{2}{1}^{\frac{7}{3}} = 5.04$.

In quantum *Go*, the rule of capturing stones is similar to classical *Go*. In Fig.S2c-d, the white classical stone on A1 is captured after the black quantum stone [B1,B10] becoming a classical stone that settled on B1. The self-capture rule and the Ko rule are also included in quantum *Go*, which is the same as classical *Go*.

As the games played by the naive bots, the boards of final states are almost filled with no legal intersections remaining to place the stones. The games ended as two bots pass the turns successively. In hundreds runs of games, the bots end the games in 400-600 moves. Fig.S3 shows the final board state of one game. The winner is the black player, which has a winning margin with 50 points, when using area scoring and komi=0. Usually, komi will be set as 6.5 or 7.5 in classical *Go*, since the black player has an advantage to place stone first. But in the game of stochastically playing, there is little advantage for the black player. In 150 stochastic games, black wins 76 games when komi is 0.

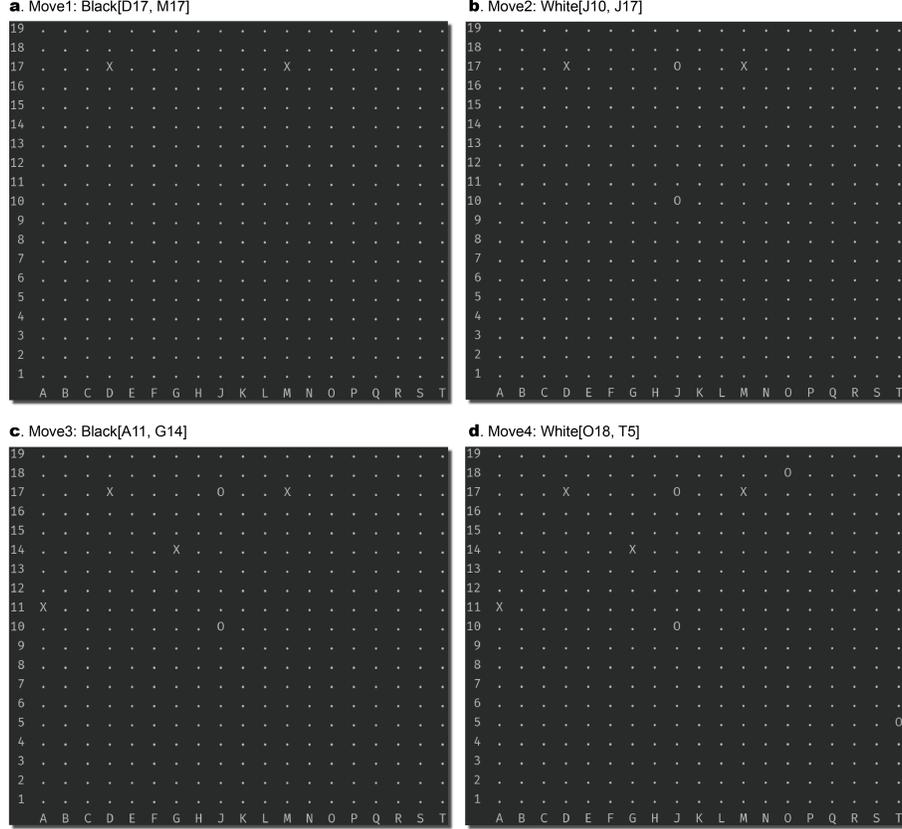


Figure S1: **The average information sets size for the first four moves of a game.** Upper case X represents black quantum stone while O represents white quantum stone. Lower case x represents black classical stone while o represents white classical stone. Dots represent the empty intersections. **a**, In move 1, after the black player places a quantum stone on D17 and M17, there is one black quantum stone on the board ($Q_{avg}^1 = 1$), so $S_{avg.info}^2 = \binom{2}{1}^1 = 2$ for the white player who is next to play. **b**, After the white player places a quantum stone on J10 and J17 in move 2, there are two quantum stones (one black and one white) on the board. So the average number of white quantum stones on board is $(\sum_{n=0}^{\frac{3}{2}} Q_{2i}) / (\frac{3}{2} + 1) = (0 + 1) / 2 = 0.5$, and $S_{avg.info}^3 = \binom{2}{1}^{0.5} = 1.4$ for the black player in move 3. **c**, There are 2 black quantum stones on the board after black3 is placed, the average number of black quantum stones on board is $(\sum_{i=1}^{\frac{3+1}{2}} Q_{2i-1}) / (\frac{3+1}{2}) = (1 + 2) / 2 = 1.5$. The information set size for the white player in move 4 is $S_{avg.info}^4 = \binom{2}{1}^{1.5} = 2.8$. **d**, In the same way, $S_{avg.info}^5 = \binom{2}{1}^1 = 2$ for the black player.

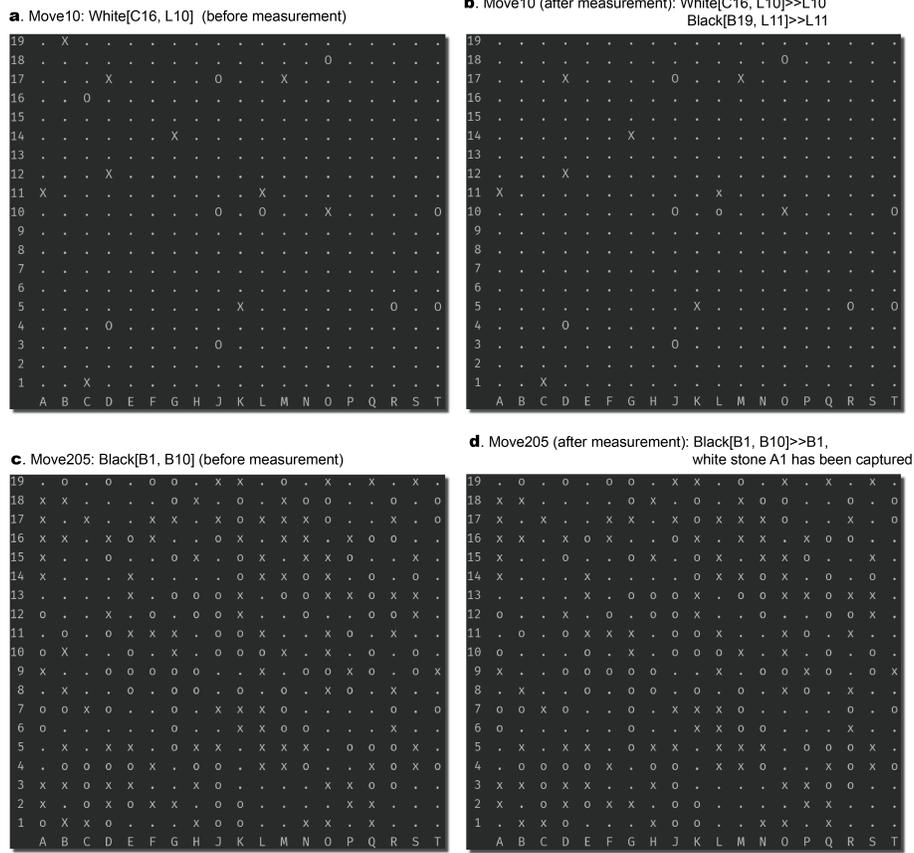


Figure S2: **Collapse measurement and stone capture.** **a-b**, In Move 10, the white quantum stone is placed on C16 and L10, which causes the collapse measurement. Two stones are measured, the white quantum stone(on [C16, L10]) is collapse to L10, and the black quantum stone(on [B19, L11]) is collapse to L11. After the measurement, there remains 4 black quantum stones and 4 white stones on the board. The average number of white quantum stones until this move is $Q_{avg}^{10} = (\sum_{i=0}^5 Q_{2i}) / (5 + 1) = (4 + \sum_{n=0}^4 n) / 6 = \frac{7}{3}$, and $S_{avg.info}^{11} = \binom{2}{1}^{\frac{7}{3}} = 5.04$. **c-d**, The black quantum stone is placed on B1 and B10 and collapses to B1 as a classical stone after the measurement. It fills up the liberties of the classical white stone on A1, which makes the stone been captured.

19	.	x	x	x	x	x	.	x	x	x	x	x	.	x	.	x	o	o	o
18	x	x	x	x	.	x	x	x	x	o	x	x	x	x	x	x	x	o	o
17	x	.	x	x	x	x	x	.	x	o	o	x	x	x	.	x	o	o	.
16	x	x	x	o	o	x	x	x	o	o	o	o	o	o	x	x	x	o	o
15	x	x	x	x	o	o	o	o	o	.	o	o	o	o	x	x	o	o	.
14	x	x	x	o	o	o	o	.	o	o	x	o	x	x	x	o	o	o	o
13	x	o	o	o	o	o	o	o	o	x	x	x	x	x	o	o	o	o	o
12	o	o	.	o	o	o	o	o	o	x	.	x	x	x	o	x	o	.	o
11	o	o	o	o	o	.	o	x	x	x	x	x	x	x	x	x	x	o	o
10	o	o	o	.	o	o	o	o	x	x	x	x	x	x	.	x	x	x	x
9	x	o	o	o	x	x	o	o	x	x	x	x	.	x	x	x	x	.	x
8	x	x	x	x	x	x	o	x	x	x	.	x	x	o	o	x	x	x	
7	x	.	x	x	x	o	x	x	x	x	x	x	o	o	o	o	x	x	
6	x	x	x	.	x	o	o	o	x	x	x	o	x	o	o	x	x	x	x
5	x	.	x	x	x	x	o	.	o	x	o	o	o	o	.	o	o	x	x
4	x	x	x	x	x	o	o	o	o	o	o	o	o	o	o	o	o	x	x
3	x	x	x	x	x	o	o	o	o	.	o	o	.	o	o	x	x	x	
2	.	x	.	o	x	x	x	x	o	o	o	o	o	o	o	x	.	x	
1	x	x	x	x	x	.	x	.	x	o	.	o	o	o	o	x	x	x	
	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T

Figure S3: **A final board state.**The game ends as the two players pass the turns consecutively. The winner is the black player and winning margin is 50 points when using area scoring and komi = 0.