



PDP  
APPLICATION NOTE

KALAH

# THE GAME OF KALAH\*



Kalah is a form of a board-game which originated thousands of years ago in the Near East. It is still widely played there and in Africa. The game has been extensively played in this country following its introduction several years ago.

## THE BOARD AND PIECES

Kalah is played by two opponents seated opposite one another across a wooden board. (Fig. 1)

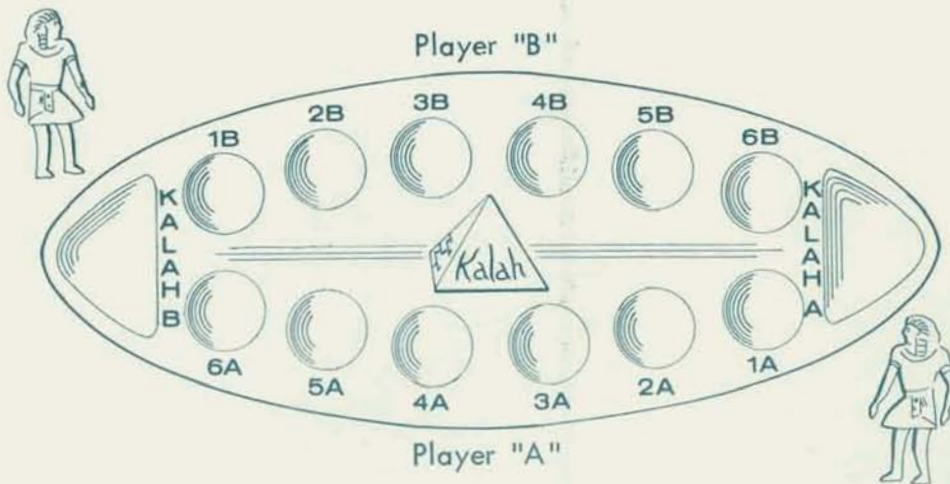


Fig. 1 Kalah Board

\*The name "Kalah", and the particular rules of play described here are copyrighted by the Kalah Game Company, Holbrook, Mass. This company produces a variety of boards and pieces for playing the game.

Each player has in front of him 6 circular holes, called his pits. At the end of the board to his right is an oval hole, called his kalah. At the beginning of the game, each pit has 3 pieces or stones in it. The two kalahs are empty. As the game proceeds, these stones are moved from hole to hole, but are never removed from the board.

### OBJECT OF THE GAME

In the course of the game stones are cast into the kalahs, but are never removed from them. The game ends when one player finds all of his pits empty. The other player then casts the stones remaining in his pits into his kalah. At this point, the player with more stones in his kalah wins.

### RULES

The players move alternately. The player whose turn it is to move behaves as follows:

- 1) He selects one of his non-empty pits.
- 2) He removes all the stones from the selected pit and casts them, one per hole, into the successive holes located counter-clockwise from the selected pit, but skipping opponent's kalah. Thus for player A (Fig. 1) the cyclic hole-order is 6A, 5A, 4A, 3A, 2A, 1A, Kalah A, 6B, 5B, 4B, 3B, 2B, 1B, 6A, . . . , while for player B the order is 6B, 5B, 4B, 3B, 2B, 1B, Kalah B, 6A, 5A, 4A, 3A, 2A, 1A, 6B, . . . .
- 3) What happens next depends on the results of the play:
  - a) If as a result of the play, all of the players' pits are empty, then the game is over.
  - b) If the last stone distributed in the play was cast into the player's kalah (repeat play), then the player must move again.
  - c) If the last stone was cast into an empty pit on the player's side of the board, opposite a non-empty pit, then a capture results: The single stone in the previously empty pit, together with all the stones in the opposite pit, are taken up and cast into player's kalah.
  - d) If neither a) nor b) occurs, the move passes to the opponent.

### EXAMPLES

Consider the position shown in Fig. 2. The contents of each hole are numbered. Suppose it is "A's" move.

- 1) He may select 6A, 4A, 3A, 2A, or 1A, but not 5A, which is empty.
- 2) Suppose he selects 2A. Then he removes the 2 stones from 2A, and casts them into 1A and kalah A. Rule 3b applies, so player A moves again. Suppose that he now selects 4A. The 2 stones in 4A are cast into 3A and 2A. 2A belongs to player A, is empty, and is opposite 5B, which is not empty. Rule 3c applies, so the 1 stone is taken from 2A, the 4 stones are taken from 5B, and these 5 stones are cast into kalah A. Then it is "B's" move (Rule 3d).

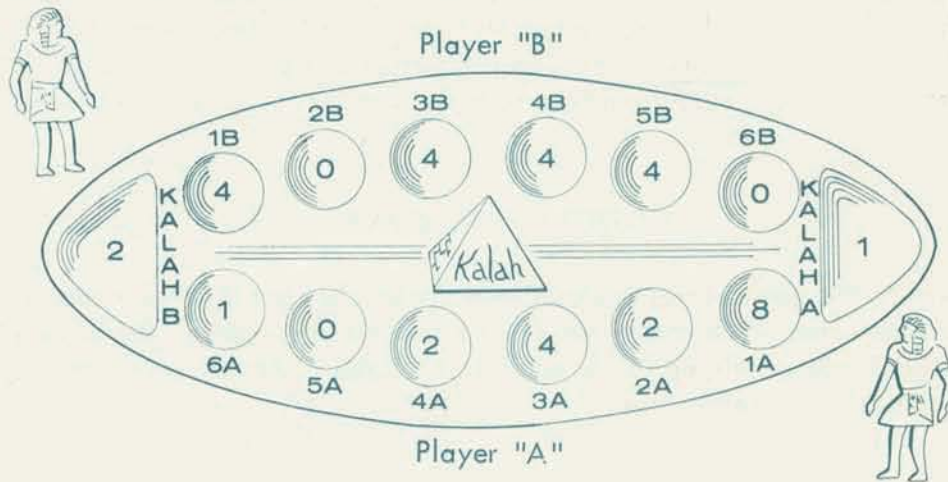


Fig. 2 Examples of moving

- 3) If "A" had selected 6A, no capture would result from the move: the one stone from 6A is cast into 5A, which is opposite an empty pit. Rule 3d applies.
- 4) If "A" had selected 3A, no capture would result: 4 stones from 3A are cast into 2A, 1A, kalah A, 6B, which is not on "A's" side of the board.
- 5) If "A" had selected 1A, he would cast the 8 stones in 1A into kalah A, 6B, 5B, 4B, 3B, 2B, 1B, and 6A (skipping kalah B).

## A PDP-1 PROGRAM FOR KALAH\*

### EXTERNAL BEHAVIOR OF THE PROGRAM

A schematic representation of the Kalah board is displayed on the cathode ray tube or typewriter. Figure 3 shows the display at the beginning of the game. On the CRT, the "+" positioned below the board mid-line indicates that it is the lower player's move.

When the board is displayed, the computer is awaiting instructions.

- 1) If the operator wishes to make a move, he types a single digit, 1,2,3,4,5, or 6, indicating the selected pit. The computer will immediately make the move, unless it is illegal (selected pit empty), in which case it will ignore the type-in.
- 2) If the operator wishes the machine to select a move, he hits the space-bar. The display will vanish from the CRT while the computer thinks. When the machine has selected a move, it backspaces, types the move, updates the board and returns to the waiting state.
- 3) If the operator wishes to restart the game instead of moving, he types carriage-return instead of 1-6 or space.†

\*This program was conceived and written by Roland Silver of Bolt, Beranek and Newman, Cambridge, Mass.

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          3   3   3   3   3   3
    0
    +
          3   3   3   3   3   3
  
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Fig. 3 PDP Cathode Ray Tube Display

- 4) The machine punctuates the sequence of moves as follows:
  - a) period after a repeat move
  - b) comma after a non-repeat move by lower player
  - c) carriage-return after a non-repeat move by upper player
  
- 5) When the game is over, the computer types which player wins, then the score, and then displays the board on the CRT without the "+". To start over, the operator types carriage-return. †

#### INTERNAL BEHAVIOR OF THE PROGRAM

The program bases its selection of a move on an exhaustive analysis of move-sequences down to a fixed depth. Its evaluation of move-sequences is based on a simple position utility:

- a) If a position is not terminal, i.e., the game is not ended, then the utility of the position is the difference between the contents of player A's kalah and player B's kalah.
  
- b) For a terminal position, the utility is the kalah-difference plus the contents of all player A's pits minus the contents of all player B's pits.

The value of a position P at level L is evaluated recursively as follows:

- 1) If P is terminal, then its value is equal to its utility.
  
- 2) If L = depth, the value of P is its utility.
  
- 3) Otherwise, all possible moves  $M_1, \dots, M_k$  available in position P are examined. Let move  $M_i$  lead to position  $P_i$ . If  $M_i$  is a repeat move, let  $V_i$  be the value of  $P_i$  at level L. If not, let  $V_i$  be the value of  $P_i$  at level  $L + 1$ .

If it is player A's move, the value V of P is  $\max.(P_1 \dots P_k)$ . If it is player B's move,  $V = \min.(P_1 \dots P_k)$ .

Given the actual position of the board, the computer will select that move which leads to a position of optional value: maximum for player A, minimum for player B.

† The machine looks ahead a number of moves to determine the best play. This number is set from the computer test word when the game is started.