

Package ‘tictactoe’

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Type Package
Title Tic-Tac-Toe Game
Version 0.2.2
Description Implements tic-tac-toe game to play on console, either with human or AI players.
Various levels of AI players are trained through the Q-learning algorithm.
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equivalent_states	<i>Equivalent States</i>
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Description

Returns a set of equivalent states and actions

Usage

```
equivalent_states(state)

equivalent_states_actions(state, action)
```

Arguments

state	state, 3x3 matrix
action	integer vector of indices (1 to 9)

Value

equivalent_states returns a list of state matrices

equivalent_states_actions returns a list of two lists: states, the set of equivalent states and actions, the set of equivalent actions

hash-ops	<i>Hash Operations for Single State</i>
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Description

Hash Operations for Single State

Usage

```
haskey(x, ...)

## S3 method for class 'xhash'
x[state, ...]

## S3 replacement method for class 'xhash'
x[state, ...] <- value

## S3 method for class 'xhash'
haskey(x, state, ...)
```

Arguments

x	object
...	additional arguments to determine the key
state	state object
value	value to assign

Value

- haskey returns a logical
- `[` returns a reference to the object
- `[<-` returns a value

ttt	<i>Play Tic-Tac-Toe Game</i>
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Description

Start tic-tac-toe game on the console.

Usage

```
ttt(player1 = ttt_human(), player2 = ttt_human(), sleep = 0.5)
```

Arguments

player1, player2	objects that inherit ttt_player class
sleep	interval to take before an AI player to make decision, in second

Details

At default, the game is played between humans. Set player1 or player2 to `ttt_ai()` to play against an AI player. The strength of the AI can be adjusted by passing the `level` argument (0 (weakest) to 5 (strongest)) to the `ttt_ai` function.

To input your move, type the position like "a1". Only two-length string consisting of an alphabet and a digit is accepted. Type "exit" to finish the game.

You may set both player1 and player2 as AI players. In this case, the game transition is displayed on the console without human inputs. For conducting a large sized simulations of games between AIs, refer to [ttt_simulate](#)

See Also

[ttt_ai](#), [ttt_human](#), [ttt_simulate](#)

Examples

```
## Not run:
ttd(ttd_human(), ttd_random())

## End(Not run)
```

ttd_ai	<i>Tic-Tac-Toe AI Player</i>
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Description

Create an AI tic-tac-toe game player

Usage

```
ttd_ai(name = "ttd AI", level = 0L)

ttd_random(name = "random AI")
```

Arguments

name	player name
level	AI strength. must be Integer 0 (weakest) to 5 (strongest)

Details

level argument controls the strength of AI, from 0 (weakest) to 5 (strongest). ttd_random is an alias of ttd_ai(level = 0).

A ttd_ai object has the getmove function, which takes ttd_game object and returns a move considered as optimal. getmove function is designed to take a ttd_game object and returns a move using the policy function.

The object has the value and policy functions. The value function maps a game state to the evaluation from the first player's viewpoint. The policy function maps a game state to a set of optimal moves in light of the value evaluation. The functions have been trained through the Q-learning.

Value

ttd_ai object

`ttd_game`*Tic-Tac-Toe Game*

Description

Object that encapsulates a tic-tac-toe game.

Usage

```
ttd_game()
```

Value

ttd_game object

Examples

```
x <- ttd_game()
x$play(3)
x$play(5)
x$show_board()
```

`ttd_human`*Human Tic-Tac-Toe Player*

Description

Create an human tic-tac-toe player

Usage

```
ttd_human(name = "no name")
```

Arguments

name player name

Value

ttd_human object

ttd_qlern

*Q-Learning for Training Tic-Tac-Toe AI***Description**

Train a tic-tac-toe AI through Q-learning

Usage

```
ttd_qlern(player, N = 1000L, epsilon = 0.1, alpha = 0.8, gamma = 0.99,
          simulate = TRUE, sim_every = 250L, N_sim = 1000L, verbose = TRUE)
```

Arguments

player	AI player to train
N	number of episode, i.e. training games
epsilon	fraction of random exploration move
alpha	learning rate
gamma	discount factor
simulate	if true, conduct simulation during training
sim_every	conduct simulation after this many training games
N_sim	number of simulation games
verbose	if true, progress report is shown

Details

This function implements Q-learning to train a tic-tac-toe AI player. It is designed to train one AI player, which plays against itself to update its value and policy functions.

The employed algorithm is Q-learning with epsilon greedy. For each state s , the player updates its value evaluation by

$$V(s) = (1 - \alpha)V(s) + \alpha\gamma\max'_s V(s')$$

if it is the first player's turn. If it is the other player's turn, replace *max* by *min*. Note that s' spans all possible states you can reach from s . The policy function is also updated analogously, that is, the set of actions to reach s' that maximizes $V(s')$. The parameter α controls the learning rate, and *gamma* is the discount factor (earlier win is better than later).

Then the player chooses the next action by ϵ -greedy method; Follow its policy with probability $1 - \epsilon$, and choose random action with probability ϵ . ϵ controls the ratio of explorative moves.

At the end of a game, the player sets the value of the final state either to 100 (if the first player wins), -100 (if the second player wins), or 0 (if draw).

This learning process is repeated for N training games. When *simulate* is set true, simulation is conducted after *sim_every* training games. This would be usefule for observing the progress of training. In general, as the AI gets smarter, the game tends to result in draw more.

See Sutton and Barto (1998) for more about the Q-learning.

Value

data.frame of simulation outcomes, if any

References

Sutton, Richard S and Barto, Andrew G. Reinforcement Learning: An Introduction. The MIT Press (1998)

Examples

```
p <- ttd_ai()
o <- ttd_qlearn(p, N = 200)
```

ttd_simulate	<i>Simulate Tic-Tac-Toe Games between AIs</i>
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Description

Simulate Tic-Tac-Toe Games between AIs

Usage

```
ttd_simulate(player1, player2 = player1, N = 1000L, verbose = TRUE,
  showboard = FALSE, pauseif = integer(0))
```

Arguments

player1, player2	AI players to simulate
N	number of simulation games
verbose	if true, show progress report
showboard	if true, game transition is displayed
pauseif	pause the simulation when specified results occur. This can be useful for explorative purposes.

Value

integer vector of simulation outcomes

Examples

```
res <- ttd_simulate(ttd_ai(), ttd_ai())
prop.table(table(res))
```

vectorized-hash-ops	<i>Vectorized Hash Operations</i>
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Description

Vectorized Hash Operations

Usage

```
haskeys(x, ...)  
  
setvalues(x, ...)  
  
getvalues(x, ...)  
  
## S3 method for class 'xhash'  
getvalues(x, states, ...)  
  
## S3 method for class 'xhash'  
setvalues(x, states, values, ...)  
  
## S3 method for class 'xhash'  
haskeys(x, states, ...)
```

Arguments

x	object
...	additional arguments to determine the keys
states	state object
values	values to assign

Value

- haskeys returns a logical vector
- setvalues returns a reference to the object
- getvalues returns a list of values

xhash

Create Hash Table for Generic Keys

Description

Create Hash Table for Generic Keys

Usage

```
xhash(convfunc = function(state, ...) state, convfunc_vec = function(states,
...) unlist(Map(convfunc, states, ...)), default_value = NULL)
```

Arguments

convfunc	function that converts a game state to a key. It must take a positional argument state and keyword arguments represented by ..., and returns a character.
convfunc_vec	function for vectorized conversion from states to keys. This function must receive a positional argument states and keyword arguments ... and returns character vector. By default, it tries to vectorize convfunc using Map. User may specify more efficient function if any.
default_value	value to be returned when a state is not recorded in the table.

Value

xhash object

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