

# AI, ALPHAGO AND COMPUTER HEX

A MATH AND COMPUTING STORY

hayward@ualberta.ca

computing.science university of alberta

2018 march

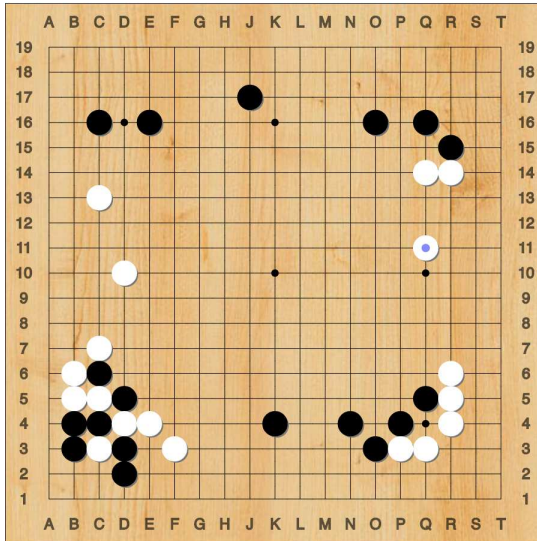
## THANKS

- **Computer Research Hex Group** Michael Johanson, Yngvi Björnsson, Morgan Kan, Nathan Po, Jack van Rijswijck, Broderick Arneson, Philip Henderson, Jakub Pawlewicz, Aja Huang **AlphaGo**, Kenny Young, Noah Weninger, Chao Gao, Martin Müller **Fuego**
- NSERC

1 EVOLUTION

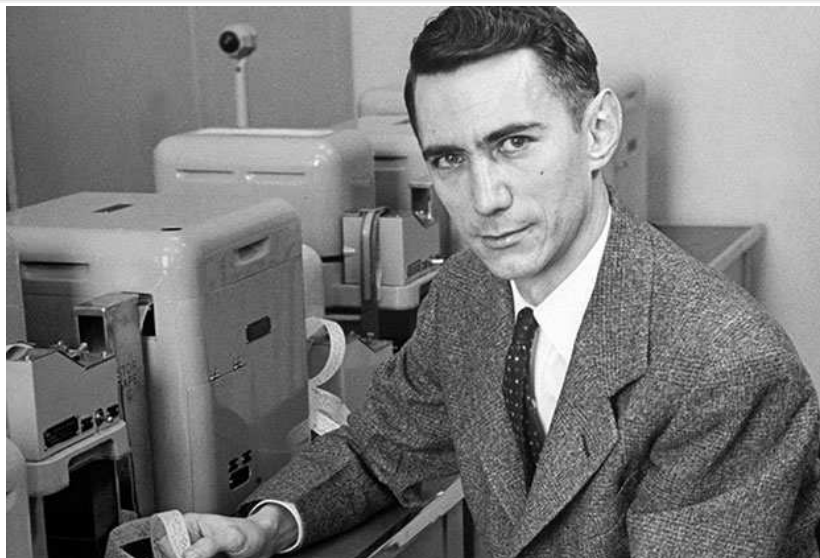
2 COMPUTER HEX

(CREDIT GOGAMEGURU)



1950 SHANNON

(CREDIT EISENSTAEDT/LIFE)



# 1950 SHANNON GAMEBOTS

- gamebot search + knowledge + evaluation
- search ? fixed depth mini-max
- 1949 chess
- 1 pawn
- 3 knight
- 3 bishop
- 5 rook
- 9 queen
- evaluation ? player material – opponent material

# 1950 SHANNON GAMEBOTS

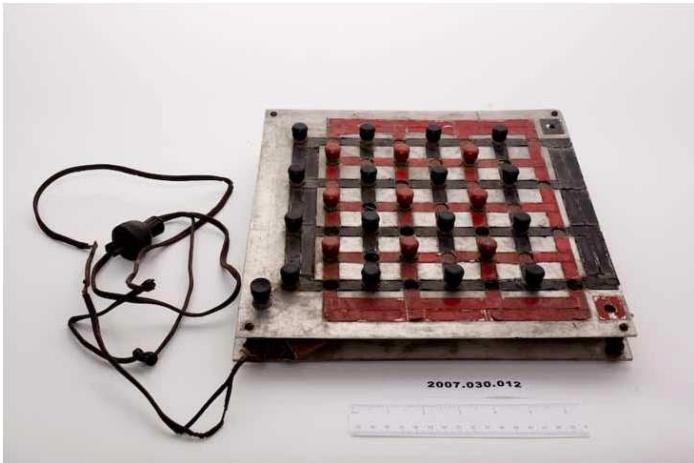
- 1950 hex
- evaluation    electric circuit saddle-points

# 1950 SHANNON GAMEBOTS

- 1950 bridg-it (bird cage)
- evaluation    electric circuit current
- move order    voltage drop



# 1950 SHANNON GAMEBOTS (CREDIT MIT MUSEUM)

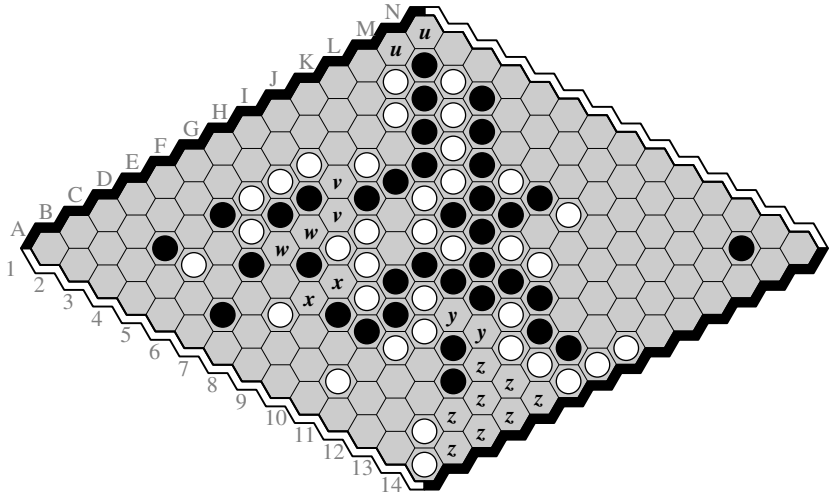


1979 BERGE

(CREDIT HOANG)



# VIRTUAL CONNECTION



# 1992 CHINOOK/SCHAEFFER TINSLEY

(JEOPAR)

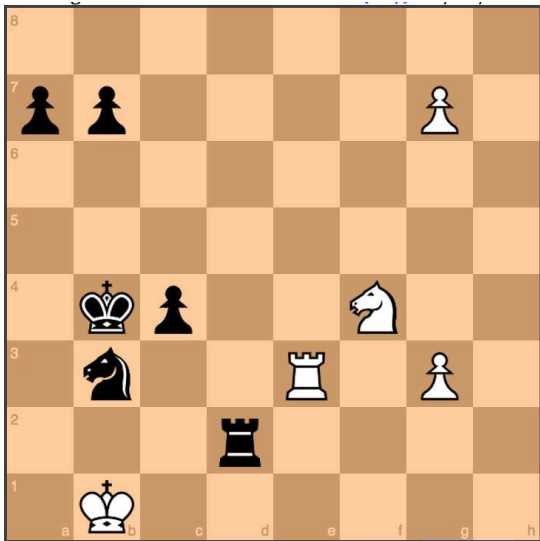


1996 Hsu-Campbell

(CREDIT NEWBORN)



# 1997 KASPAROV-DB 5 (CREDIT CHESSGAMES.COM)



# DEEP BLUE - KASPAROV

- 1996 2 - 4
- 1997 3.5 - 2.5
- why so soon? ... accurate evaluation ...

# 1992 TESAURO

(CREDIT IBM)





# 1992 TESAURO TD-GAMMON

- search ? 2-ply minimax
- evaluation ? learned !
- how ? neural network (function approximator)
- training ? temporal difference learning
- improvement stops after 1 500 000 self-play games

1995 MÜLLER

(CREDIT MÜLLER)



# 1995 MÜLLER COMPUTER GO

- Explorer life and death
- Fuego open source gobot
- 2009 ICGA 9x9 gold

# 1998 SUTTON REINFORCEMENT LEARNING



2006 COULOM

(CREDIT HIROSHI YAMASHITA)



# 2006 COULOM MONTE CARLO TREE SEARCH

- exploitation best-first search
- exploration bandit arm selection (Kocsis-Czepesvari)
- evaluation ? randomized playouts + knowledge  
(response patterns)
- 2006 ICGA 9x9 gold

2007 SILVER

(CREDIT SILVER)



## 2007 SILVER

- 2007 Combining online and offline knowledge in UCT
- 2007 RL Local Shape Game of Go
- 2009 RL + simulation-based search in computer Go
- supervisors Müller-Sutton



2006 ARNESON BJ H HENDERSON K

(ICGA)



# 2010 EWALDS

(CREDIT ICGA)



2010 HASSABIS

(CREDIT HASSABIS)



# 2010 HASSABIS ET AL. DEEPMIND

- Silver consultant, University College London
- Silver DM fulltime 2013

# FLEET

(CREDIT UoFT)



# 2012 HINTON

(CREDIT UoFT)



# 2012 HINTON IMAGE CLASSIFICATION



# 2012 HINTON IMAGE CLASSIFICATION

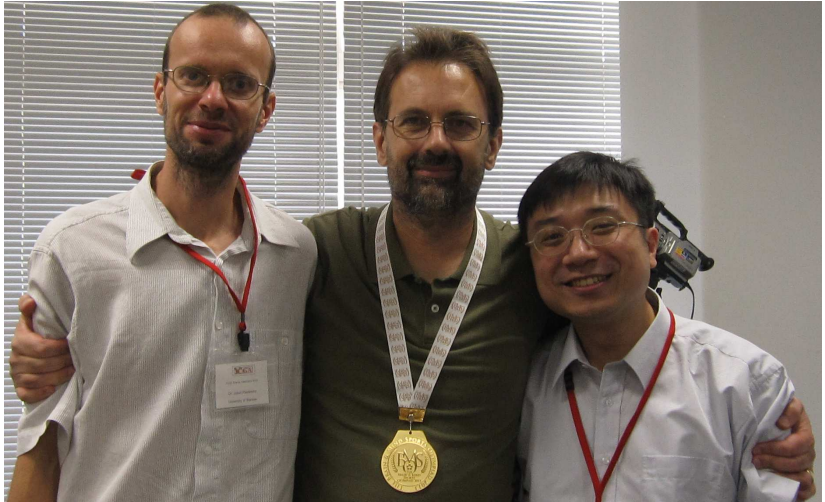




# 2012 HINTON IMAGE CLASSIFICATION

- Imagenet Classification with DCNNs

# 2013 PAWLEWICZ H HUANG



## 2013 HUANG

- 2003 gobot Erica
- 2011 phd supervisor Coulom
- 2012-13 UAlberta postdoc, supervisors Müller + Hayward
- 2013 ICGA Hex gold MoHex (H A H Huang Pawlewicz)
- 2014 Google DeepMind \$.5 billion
- Huang joins DeepMind

# 2014 COULOM (CREDIT TAKASHI OSATO/WIRED)



## 2014 COULOM

- 2010 Unbalance: Zen gobot competitor ?
- commercial Crazystone
- Wired mystery of Go, ancient game that computers still can't solve
- 2014 UEC Cup Densei-sen  
crazystone +4 > Norimoto Yoda 9P

# 2014 CLARK AND STORKEY



# 2014 CLARK AND STORKEY GO AND DCNNs

- Teaching DCNNs to play Go
- 2015 Maddison Huang Sutskever Silver
- Move Evaluation in Go Using DCNNs
- Go position policy net
- <https://chrisc36.github.io/deep-go/>

# MEANWHILE ... 2015 ICGA LEIDEN

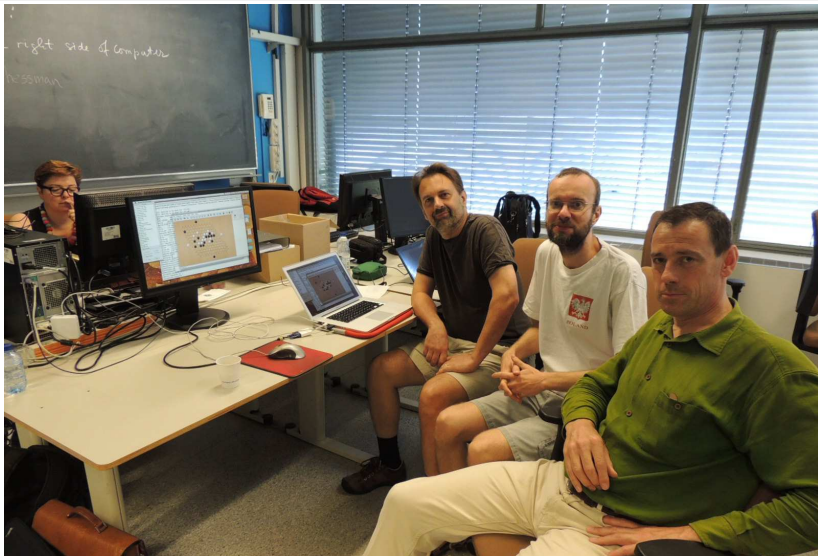




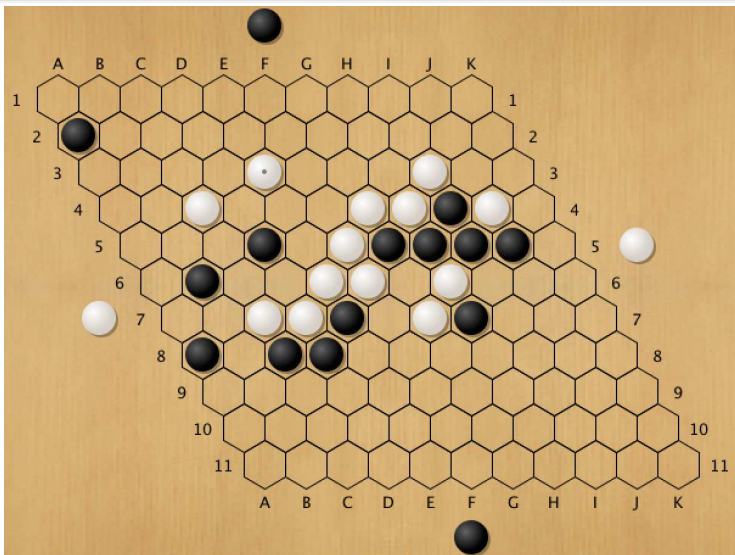
# MEANWHILE ... 2015 ICGA LEIDEN



# MEANWHILE ... 2015 ICGA LEIDEN



# MEANWHILE ... 2015 ICGA LEIDEN



2016 JAN 28

(CREDIT NATURE)



## 2016 JAN 28 NATURE

- human game records: fast policy net
- fast net, self-play RL (gradient): stronger policy net
- strong net, self-play games RL (regression): value net
- mcts + value net + fast policy net
- 20 people, > 1 000 TPU years
- AG 5-0 Fan Hui 2p (fast games 3-2)

2015 AG-FAN HUI

(CREDIT DEEPMIND)



# 2017 MARCH SEOUL AG vs LS

[https://www.youtube.com/watch?v=8tq1C8spV\\_g](https://www.youtube.com/watch?v=8tq1C8spV_g)

<https://gogameguru.com/tag/deepmind-alphago-lee-sedol>

<https://gogameguru.com/go-commentary-lee-sedol-vs-alpha>

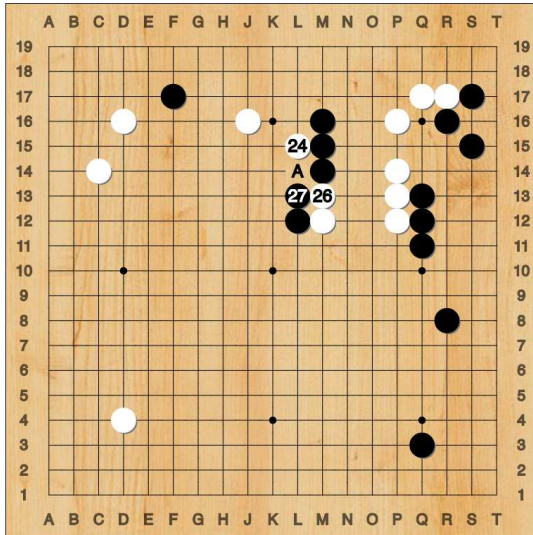
# 2017 MARCH SEOUL AG vs LS

(CREDIT GGG)

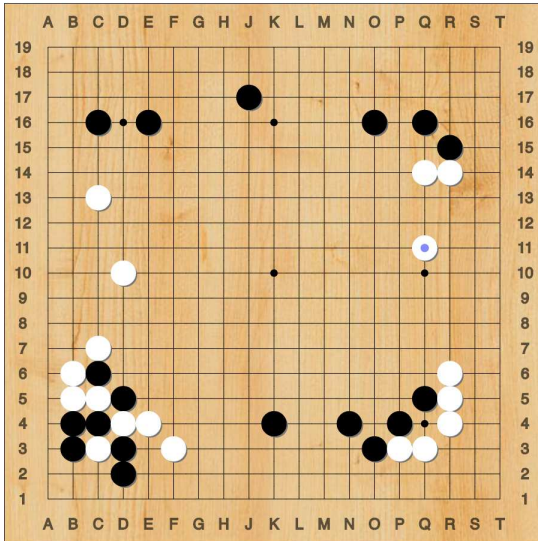




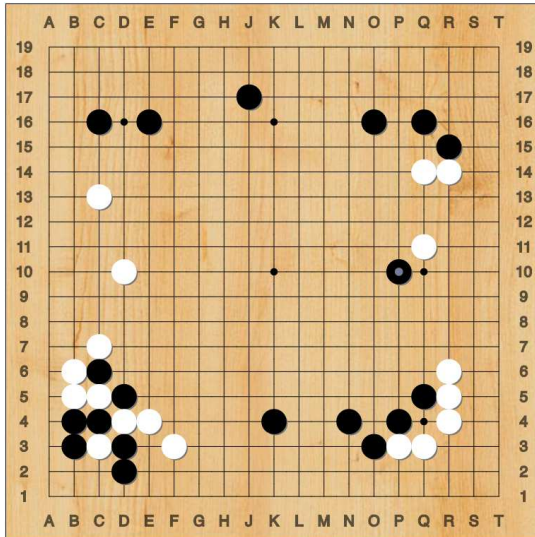
# 2017 MARCH SEOUL AG vs LS



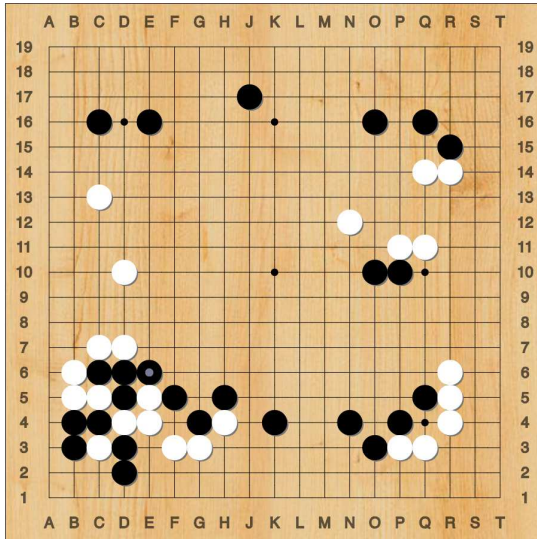
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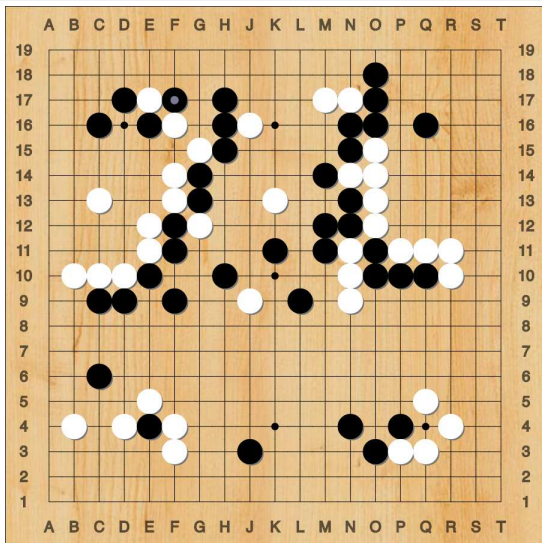
# 2017 MARCH SEOUL AG vs LS



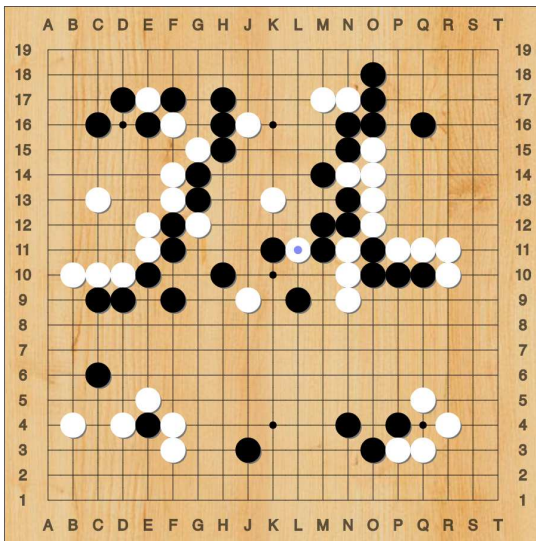
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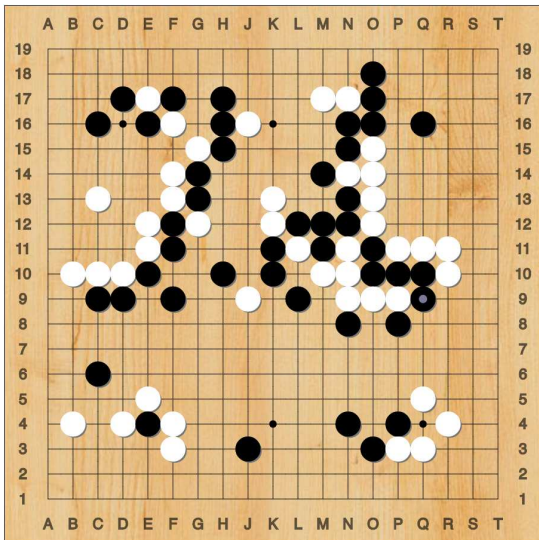
# 2017 MARCH SEOUL AG vs LS



# 2017 MARCH SEOUL AG vs LS



# 2017 MARCH SEOUL AG vs LS



## POST-MATCH (EWALDS)

it was incremental improvements,  
just 20-100 elo per week :)

[100 elo = 64 %]



## POST-MATCH (EWALDS)

If deepmind hadn't done it, someone else would've done it within the year. Facebook was on the right track. Deepmind had published a neural network go paper in Jan a year ago, so I'm sure all the other programs were working on it too.

## POST-MATCH (EWALDS)

It'll take a few years to scale this all down to run on reasonable hardware, though I'm not sure who will do that. It'll happen though.

## 2017 OCT 19 NATURE

- Mastering the game of Go without human knowledge
- tabula rasa
- different network (more training ?)
- after 40 days training: AG0 100-0 AG

<https://deepmind.com/blog/alphago-zero-learning-scratch>

# 2018 MARCH AGM VS KE JIE (CREDIT GOOGLE)

- online early 2017: fast games AG Master 60-0 humans 9P

# 2018 MARCH AGM VS KE JIE (CREDIT GOOGLE)



# AG (2014 - 2017)

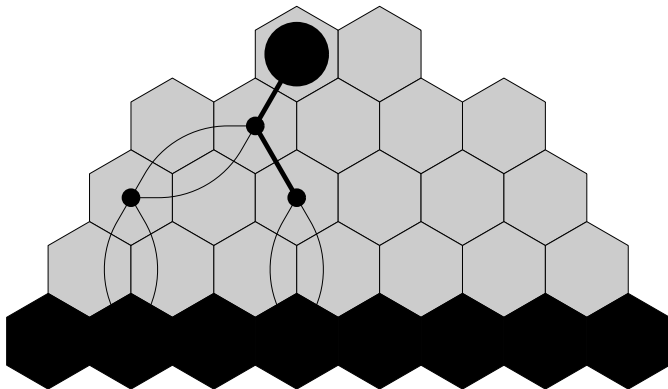
- leela, fine art, crazystone, zen

## AG (2014 - 2017)

unanswered ?

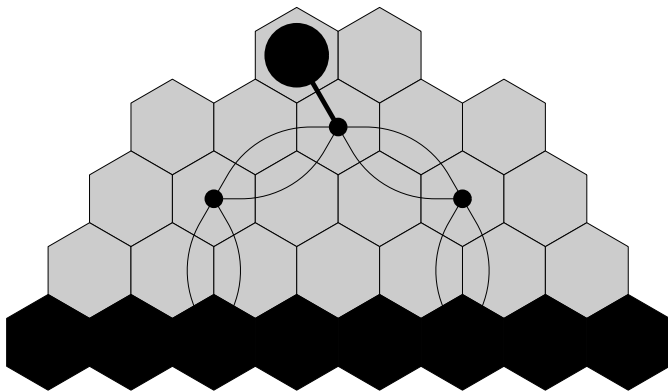
- solve ? 6x6 still open
- true komi ?
- careful endgame play ?
- distance from perfect play?
- handicap AG0 vs Ke Jie ? 2 stones ?

# VIRTUAL CONNECTIONS

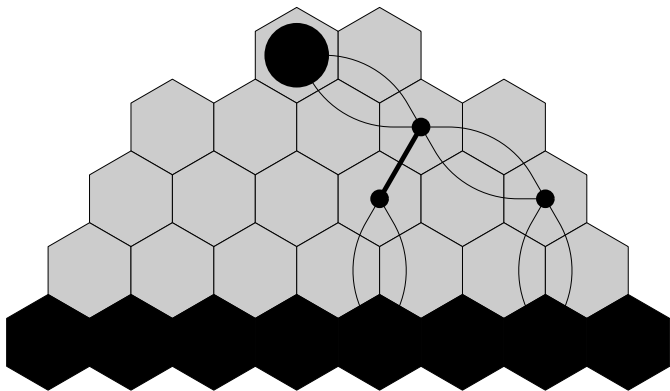




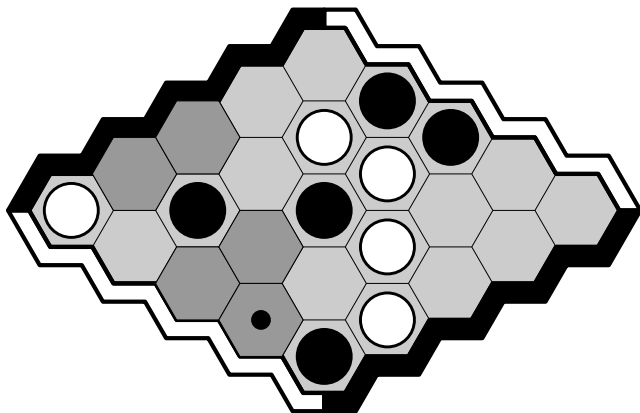
# VIRTUAL CONNECTIONS



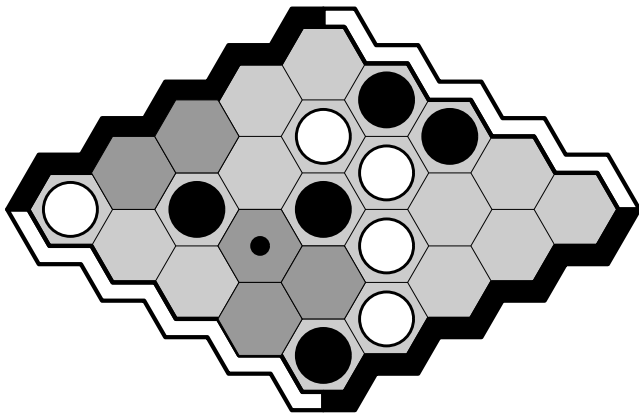
# VIRTUAL CONNECTIONS



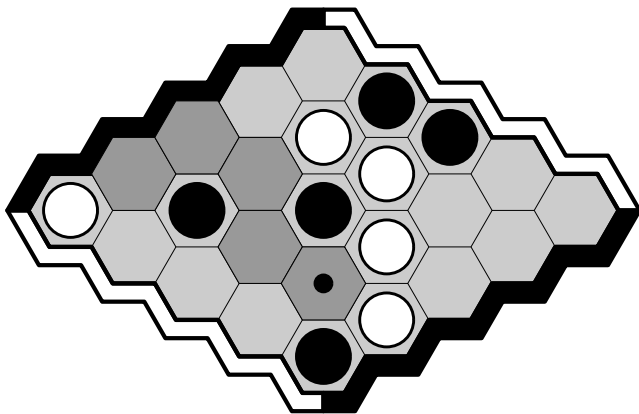
# MUSTPLAY



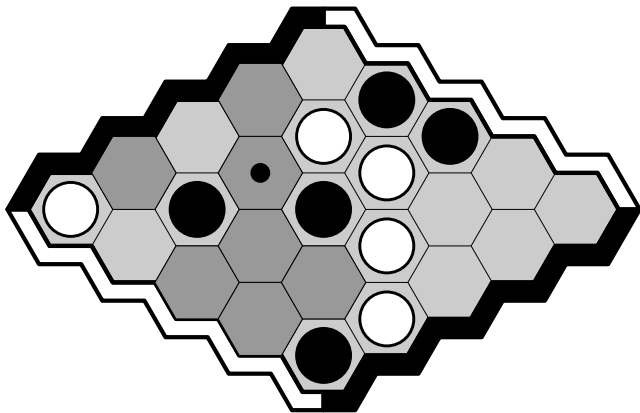
# MUSTPLAY



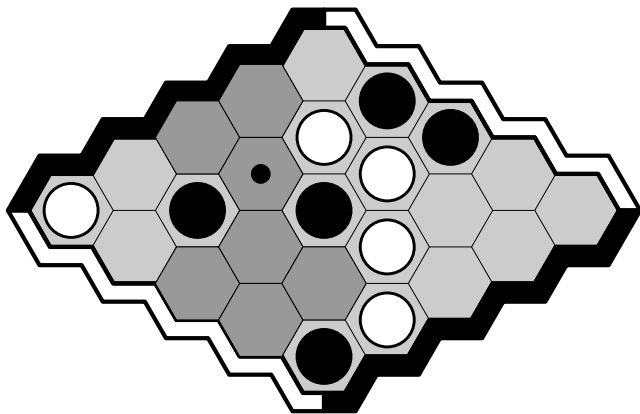
# MUSTPLAY



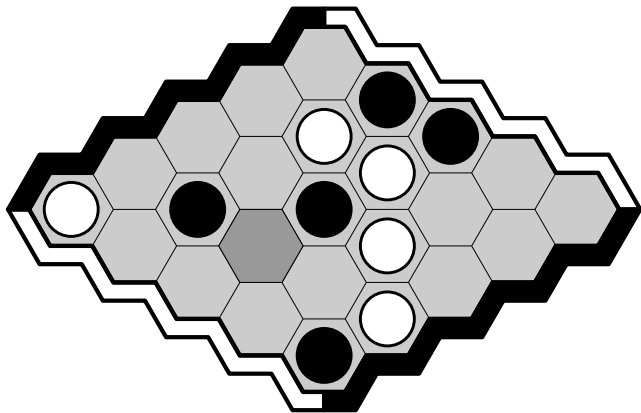
# MUSTPLAY



# MUSTPLAY

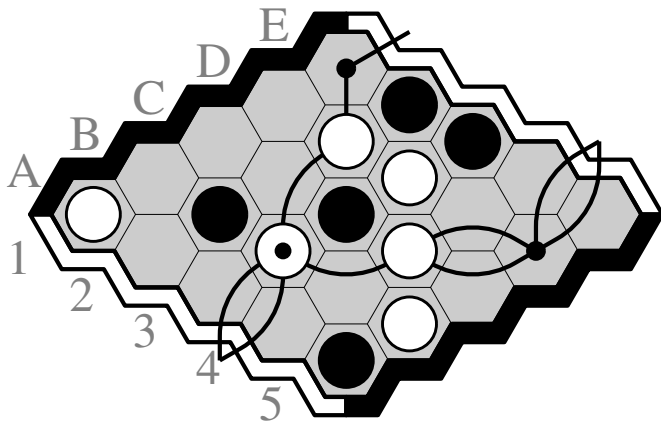


# MUSTPLAY

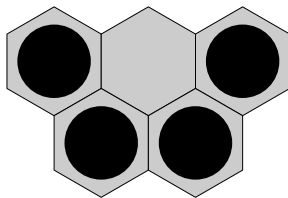




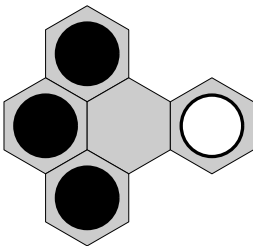
## MUSTPLAY



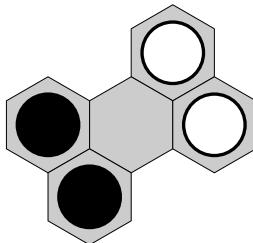
# INFERIOR CELLS: DEAD



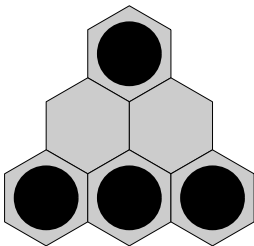
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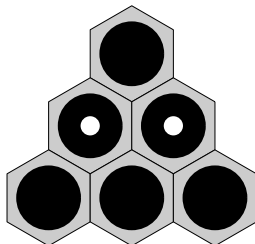
# INFERIOR CELLS: DEAD



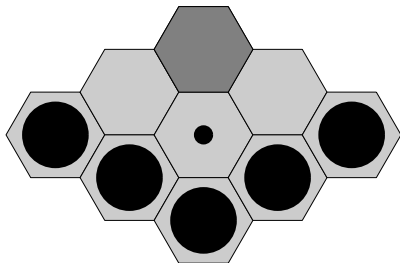
# INFERIOR CELLS: CAPTURED



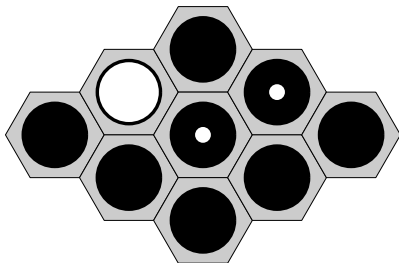
# INFERIOR CELLS: CAPTURED



# INFERIOR CELLS: PERMANENT

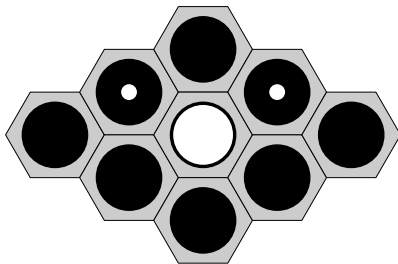


# INFERIOR CELLS: PERMANENT

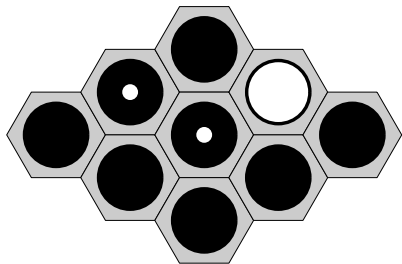




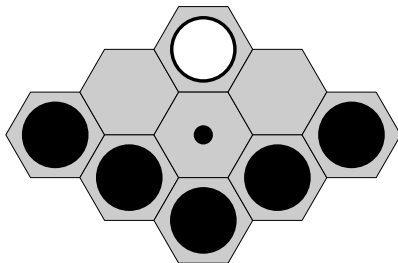
# INFERIOR CELLS: PERMANENT



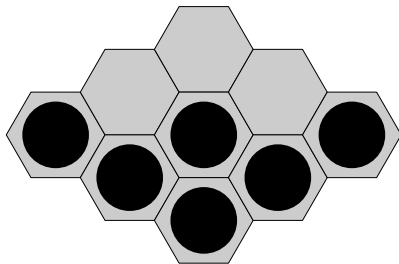
# INFERIOR CELLS: PERMANENT



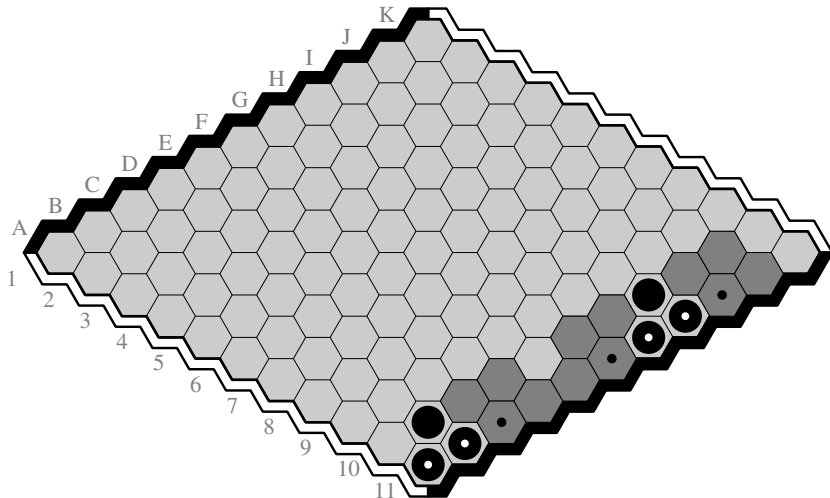
# INFERIOR CELLS: PERMANENT



# INFERIOR CELLS: PERMANENT



# INFERIOR CELLS: HANDICAP



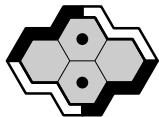
## FINDING STRATEGIES

- up to 4x4 ...
- find 1pw ? easy
- find win/loss value for each 1st move ? not hard
- 5x5 ? harder
- 6x6 ? ? unknown

# WINNING HEX OPENINGS

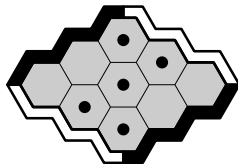


# WINNING HEX OPENINGS

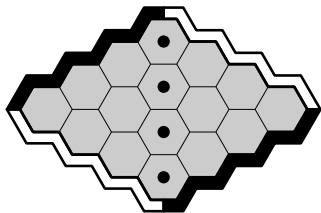




# WINNING HEX OPENINGS

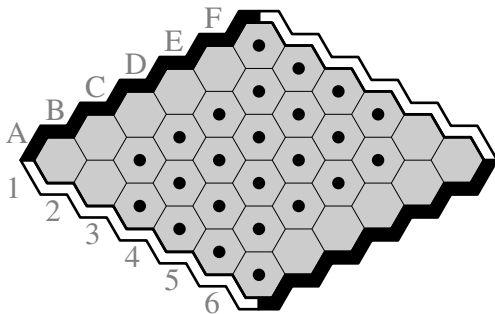


# WINNING HEX OPENINGS

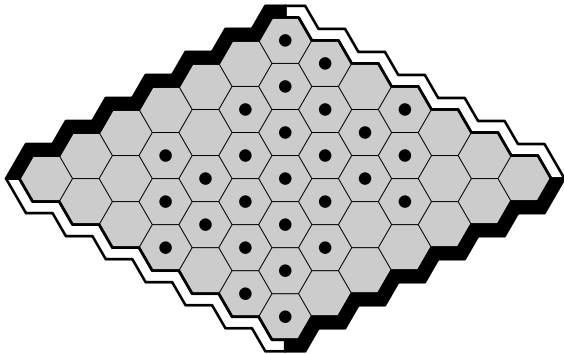




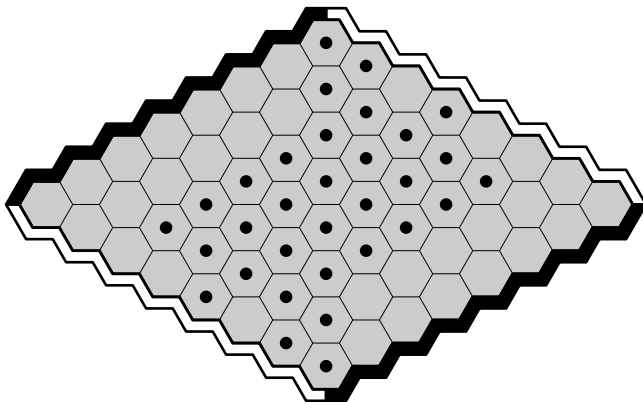
# WINNING HEX OPENINGS 1995



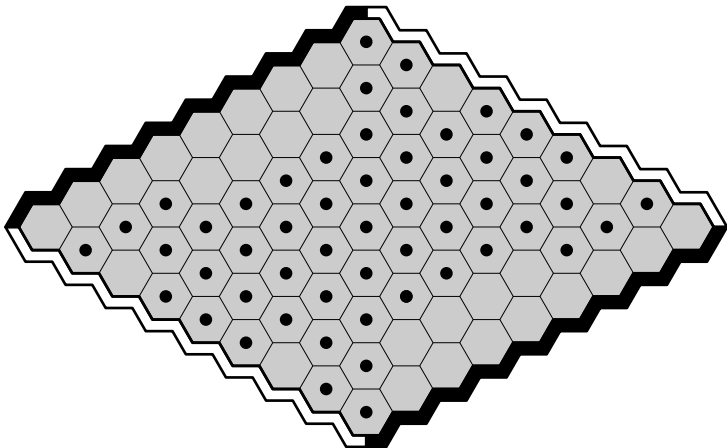
# WINNING HEX OPENINGS 2004



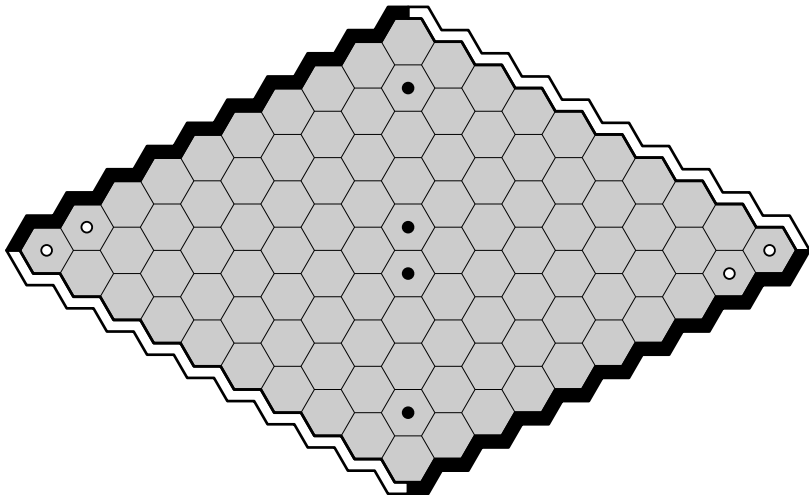
# WINNING HEX OPENINGS 2009



# WINNING HEX OPENINGS 2013

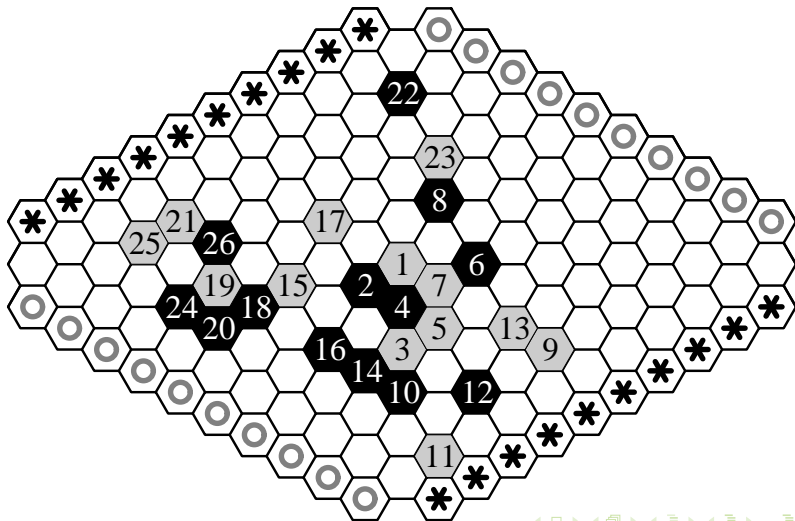


# WINNING HEX OPENINGS 2014





# TWIST AND TURN: STORY OF HEX (2018)



THANK YOU

