DKE Games Group – Seminar

The Ludii General Game System

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Outline

Introduction

- Digital Ludeme Project
- Ludii

Ludii Team

- Cameron Browne
- Eric Piette
- Matthew Stephenson
- Walter Crist
- Dennis Soemers

Evidence of Games

Evidence of ancient board games:

- Boards, pieces, dice, etc.
- Last 5,000 years
- Most cultures worldwide

But almost never the rules!

Understanding of ancient games

- Based on modern (flawed) interpretations

Digital Ludeme Project

Five-year research project:

- Funded by the ERC (€2m)
- DKE

1. **Model**
   Full range of traditional strategy games in a single playable digital database

2. **Reconstruct**
   Missing knowledge about ancient games

3. **Map**
   Spread of games throughout history

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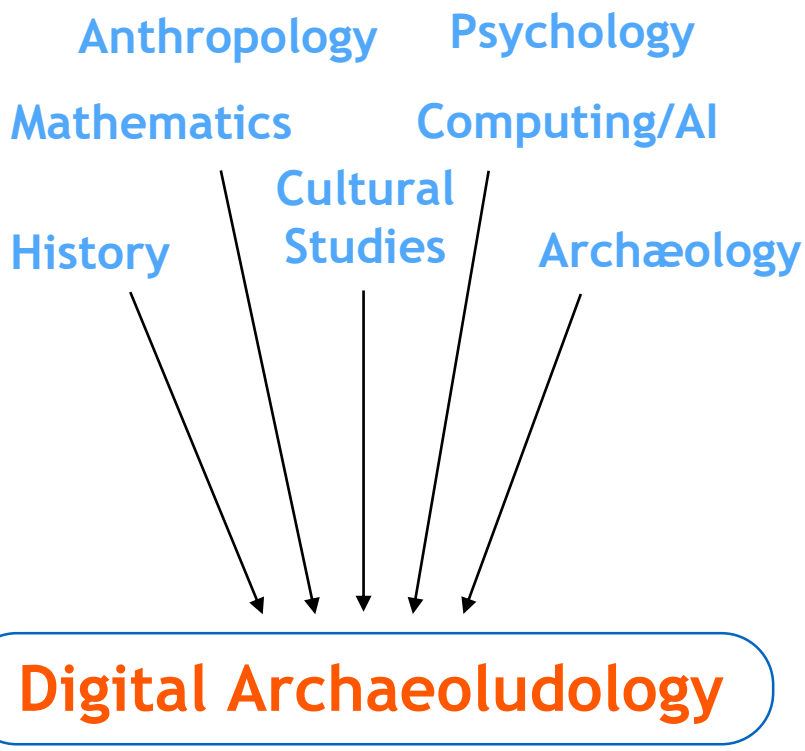
Digital Archaeoludology

New research field:
- to improve our understanding of ancient games
- by applying modern computational analysis
- to the available (partial) evidence

Bridge between:
- Traditional game studies
- Current game AI research



Ludemes

A *ludeme* is a “game meme”
- Unit of game-information information
- Building blocks or “DNA” of games

Break games down into components:
- Equipment + geometry
- Rules

Allows the full range of games to be:
- Described
- Implemented
- Compared

Ludemic Model

Games as structured ludeme trees:

```
(game "???"
    (players 2)
    (equipment {
        (board (square 3))
        (piece "Disc" P1)
        (piece "Cross" P2)
    })
    (rules
        (play (move Add (to (sites Empty))))
        (end (if (is Line 3) (result Mover Win)))
    )
)
```

Ludemic Model

Games as structured ludeme trees:

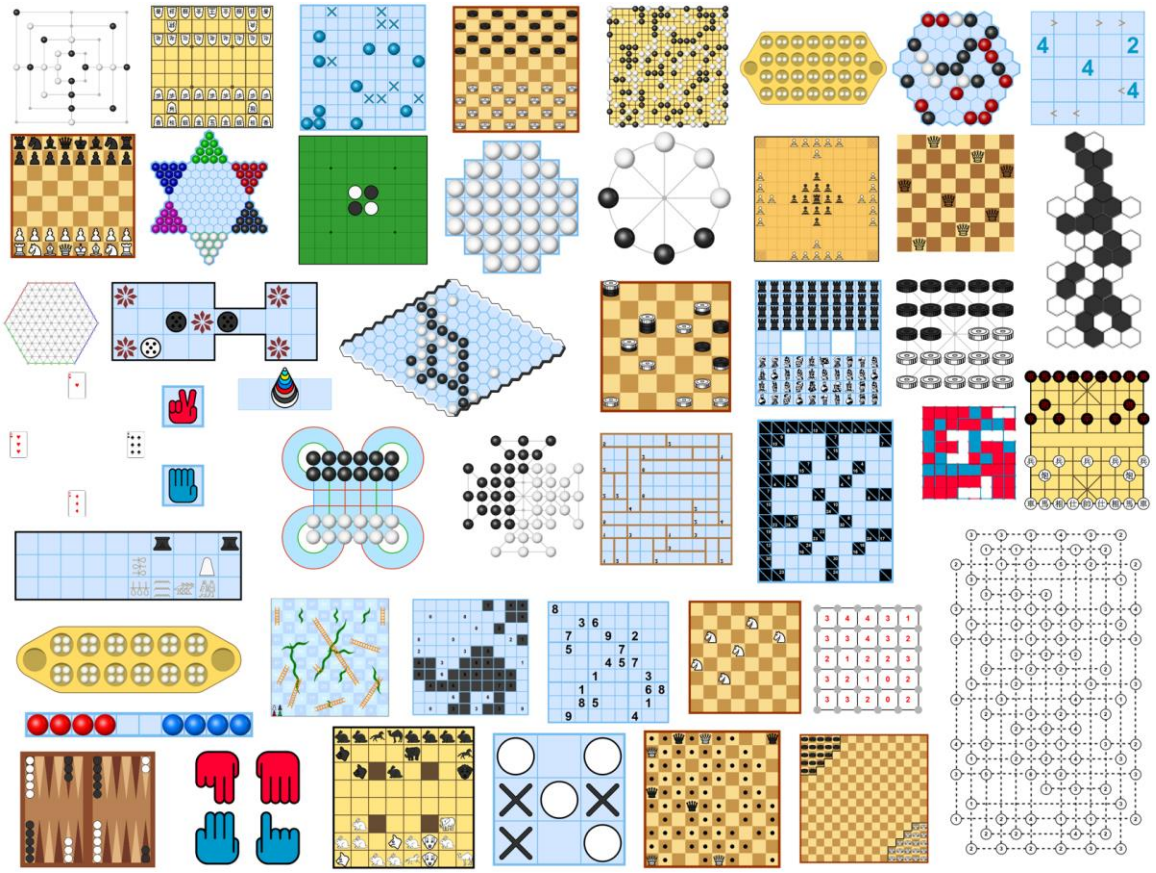
```
(game "Tic-Tac-Toe"
    (players 2)
    (equipment {
        (board (square 3))
        (piece "Disc" P1)
        (piece "Cross" P2)
    })
    (rules
        (play (move Add (to (sites Empty))))
        (end (if (is Line 3) (result Mover Win)))
    )
)
```

Ludii

Software tool for performing the analysis

General game system
- Playing
- Analysing
- Reconstructing
- Generating

Available at:
- http://ludii.games



Eric

The past of General Game Playing…

General Game Description (GDL)

- Academic standard
- **N players, turn based, finite, deterministic, full information games**
- Exists for 16 years, **52 (really different) games**
- A lot of General Game players exist: **MCTS**, (S)CSP, ASP, logic programming, …
- A low number of moves/playouts per second
- No automatic User Interface (no GUI)

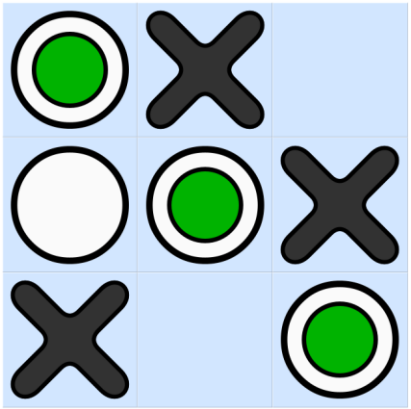
A GDL Game…

Which game is that?

```
(role white) (role black)
(init (cell 1 1 b)) (init (cell 1 2 b)) (init (cell 1 3 b))
(init (cell 2 1 b)) (init (cell 2 2 b)) (init (cell 2 3 b))
(init (cell 3 1 b)) (init (cell 3 2 b)) (init (cell 3 3 b))
(init (control white))
(<= (legal ?w (mark ?x ?y)) (true (cell ?x ?y b))
    (true (control ?w)))
(<= (legal white noop) (true (control black)))
(<= (legal black noop) (true (control white)))
(<= (next (cell ?m ?n x)) (does white (mark ?m ?n))
    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n o)) (does black (mark ?m ?n))
    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n ?w)) (true (cell ?m ?n ?w))
    (distinct ?w b))
(<= (next (cell ?m ?n b)) (does ?w (mark ?j ?k))
    (true (cell ?m ?n b)) (or (distinct ?m ?j)
    (distinct ?n ?k)))
(<= (next (control white)) (true (control black)))
(<= (next (control black)) (true (control white)))
(<= (row ?m ?x) (true (cell ?m 1 ?x))
    (true (cell ?m 2 ?x)) (true (cell ?m 3 ?x)))
(<= (column ?n ?x) (true (cell 1 ?n ?x))
    (true (cell 2 ?n ?x)) (true (cell 3 ?n ?x)))
(<= (diagonal ?x) (true (cell 1 1 ?x))
    (true (cell 2 2 ?x)) (true (cell 3 3 ?x)))
(<= (diagonal ?x) (true (cell 1 3 ?x))
    (true (cell 2 2 ?x)) (true (cell 3 1 ?x)))
(<= (line ?x) (row ?m ?x))
(<= (line ?x) (column ?m ?x))
(<= (line ?x) (diagonal ?x))
(<= open (true (cell ?m ?n b))) (<= (goal white 100) (line x))
(<= (goal white 50) (not open) (not (line x)) (not (line o)))
(<= (goal white 0) open (not (line x)))
(<= (goal black 100) (line o))
(<= (goal black 50) (not open) (not (line x)) (not (line o)))
(<= (goal black 0) open (not (line o)))
(<= terminal (line x))
(<= terminal (line o))
(<= terminal (not open))
```

And with Ludii ?

```
(game "Tic-Tac-Toe"
 (players 2)
 (equipment {
  (board (square 3))
  (piece "Disc" P1)
  (piece "Cross" P2)
 })
 (rules
  (play
   (move Add (to (sites Empty)))
  )
  (end
   (if (is Line 3)(result Mover Win))
  )
 )
)
```



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```
(role white) (role black)
(init (cell 1 1 b)) (init (cell 1 2 b)) (init (cell 1 3 b))
(init (cell 2 1 b)) (init (cell 2 2 b)) (init (cell 2 3 b))
(init (cell 3 1 b)) (init (cell 3 2 b)) (init (cell 3 3 b))
(init (control white))
(<= (legal ?w (mark ?x ?y)) (true (cell ?x ?y b))
    (true (control ?w)))
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(<= (next (cell ?m ?n x)) (does white (mark ?m ?n))
    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n o)) (does black (mark ?m ?n))
    (true (cell ?m ?n b)))
(<= (next (cell ?m ?n ?w)) (true (cell ?m ?n ?w))
    (distinct ?w b))
(<= (next (cell ?m ?n b)) (does ?w (mark ?j ?k))
    (true (cell ?m ?n b)) (or (distinct ?m ?j)
    (distinct ?n ?k)))
(<= (next (control white)) (true (control black)))
(<= (next (control black)) (true (control white)))
(<= (row ?m ?x) (true (cell ?m 1 ?x))
    (true (cell ?m 2 ?x)) (true (cell ?m 3 ?x)))
(<= (column ?n ?x) (true (cell 1 ?n ?x))
    (true (cell 2 ?n ?x)) (true (cell 3 ?n ?x)))
(<= (diagonal ?x) (true (cell 1 1 ?x))
    (true (cell 2 2 ?x)) (true (cell 3 3 ?x)))
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(<= (goal black 50) (not open) (not (line x)) (not (line o)))
(<= (goal black 0) open (not (line o)))
(<= terminal (line x))
(<= terminal (line o))
(<= terminal (not open))
```

Ludii

- **General Game System** capable of modelling all the games of the DLP project (and more)
- **Open source** github.com/Ludeme/Ludii
- **Granular** description of the games in **ludemes.** Clear, simple and short
- **Currently, between 2 to 10 times faster than GDL**
- **Can model**:
  - Deterministic / Stochastic
  - Complete / Hidden Info.
  - Puzzles / Multi-Player Games
  - Alternating / Simultaneous
  - Borderless / Any geometry
  - Math, Race, Sow, Space, War Games, …
  - Stacking games, large pieces, …

Ludii Library

~1000 games, 1100+ rulesets, ~2,000,000 option combinations

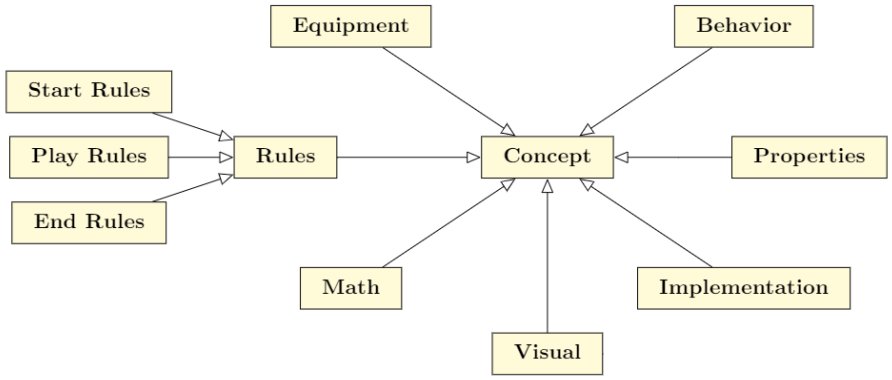
Board Game Concepts

- A **game concept** = Feature expressed in-game terms commonly used by game players and designers which can be associated with the game or an element of play.

- Examples:

- In General Game Playing (board games), the concepts **are under-exploited**

Game Concepts in Ludii



- **Properties**: Related to the format of the game
- **Equipment**: Related to the board and pieces
- **Rules**: Related to each rule (start, play, end)
- **Math**: Related to fields of Mathematics
- **Behavior**: Related to well-known game metrics
- **Visual**: Related to the game's graphical style
- **Implementation**: Related to implementation details

To organise the concepts, a taxonomy is proposed:
ludii.games/searchConcepts.php

Dennis

AI for Ludii and DLP

- Want AI to play approx. 1,000 distinct games (+ procedurally generated ones)
  - General search algorithms
  - General training algorithms
    - Also efficient training algorithms

General Game Playing

- General Game Playing (GGP)
- Require AI to play **any** arbitrary game
  - Game defined in game description language
  - No domain knowledge
  - No preparation / training time
    - Or very little
    - Arbitrary GGP competition rules

Our Problem

- Prefer minimal use of domain knowledge
  - Don’t want to handcraft for 1,000 games
- Prefer using relatively little training time
  - Since we have to repeat process 1,000x
- But can break either or both of these rules if we want
  - Logistical limitations, not arbitrary GGP competition rules

Tree Search Algorithms

- MCTS
  - Popular in GGP
  - Huge number of possible extensions
    - Some require domain knowledge, some don't
- Alpha-Beta
  - Requires (game-dependent) heuristic evaluation functions
  - Given (even simple) heuristics, can often outperform MCTS with low time budgets

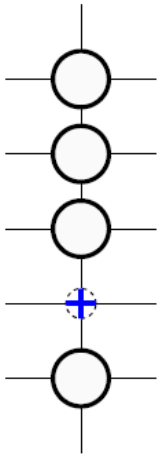
General Domain Knowledge

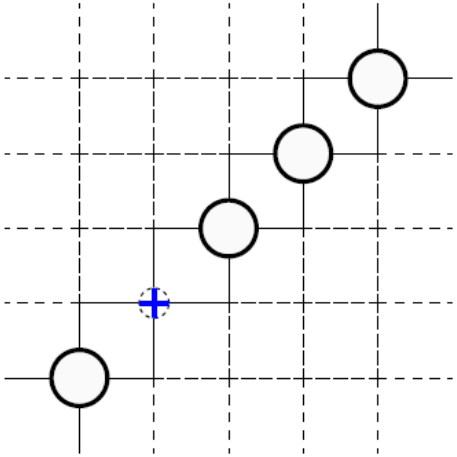
- We primarily care about a restricted set of problems
  - "Real-world" abstract games
  - Mostly board games
  - Can use domain knowledge
    - Not knowledge about any given game…
    - … but knowledge about games (as a set)

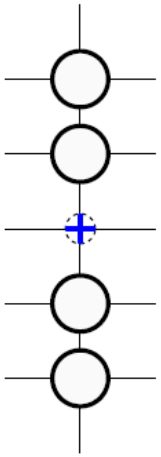
Real-World Board Game Knowledge

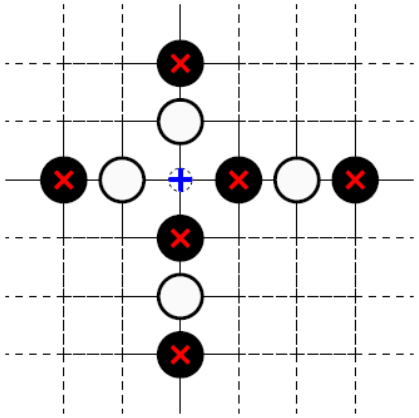
- Spatial semantics (patterns) matter
- Pieces matter
- Lines/connections of pieces matter
- Distances / proximities matter
  - To the centre, sides, corners, special regions, …
- Scores (if defined by game) matter
- For all the above: *usually*
  - But that's good enough

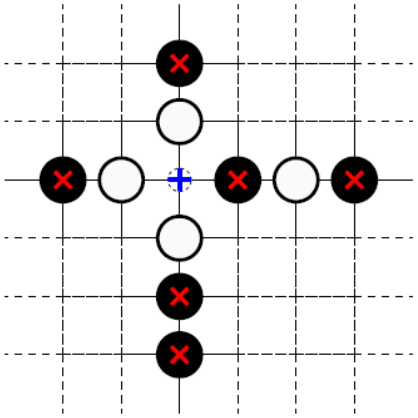
Spatial State-Action Features

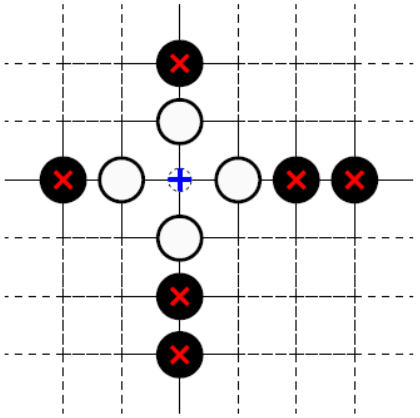




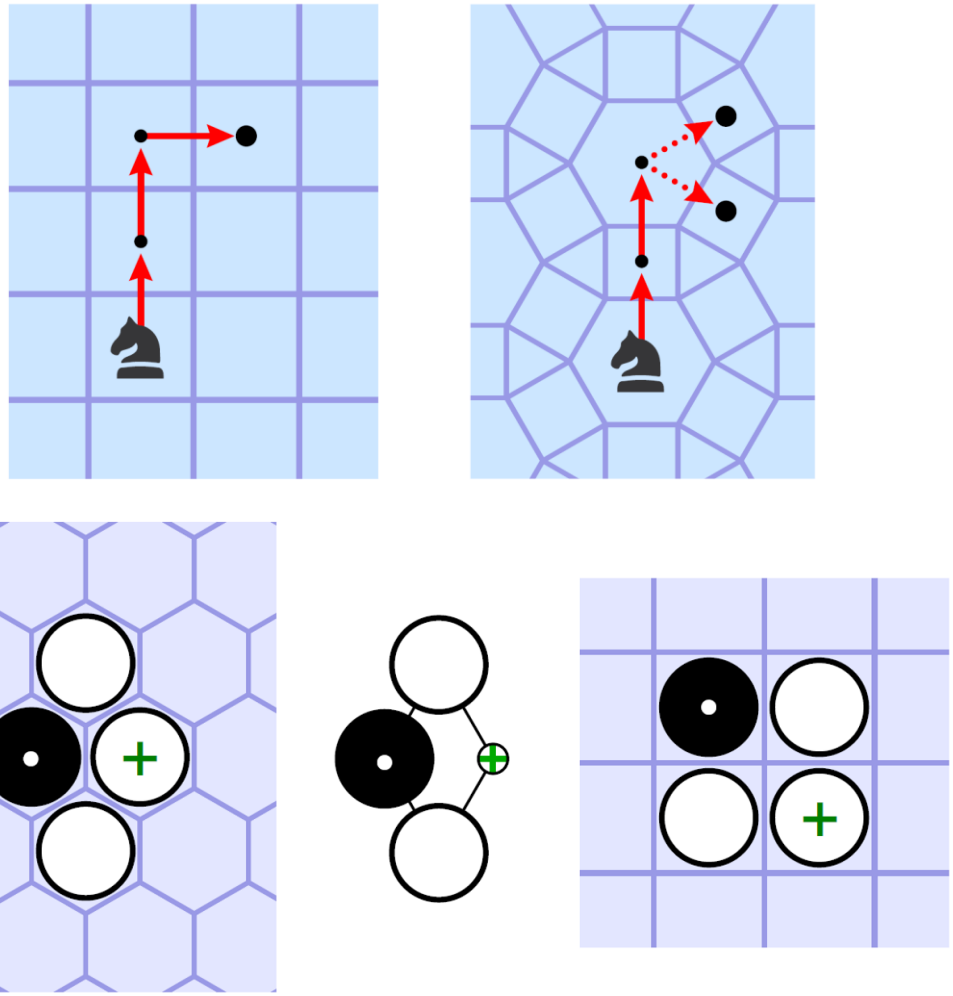




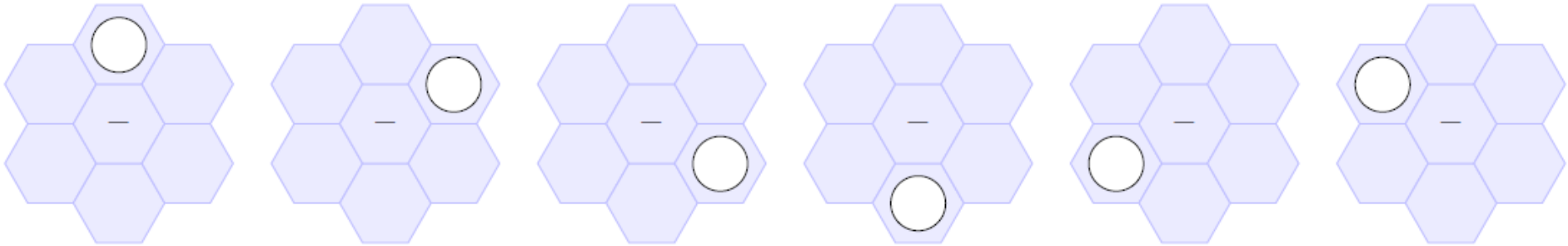


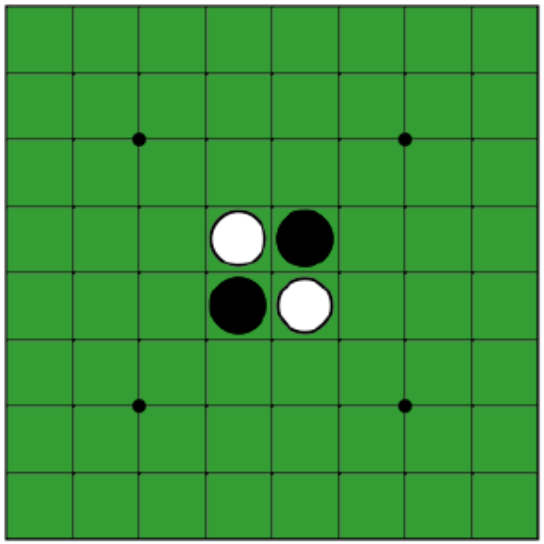


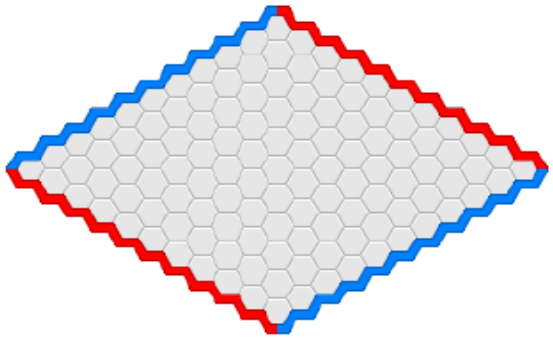
Spatial State-Action Features



Fast Learning: Symmetries







Walter

Traditional Games

- Learned through interpersonal interaction
- Can be placed within a cultural context
- Not invented for commercial sale
- Often played on ground, with readily available objects
- Rules rarely written down

Alquerque Players in Comoros, 2019

Egyptian sailors playing the game *Mn*, 2125–1940 BCE

Evidence-based Historical Data

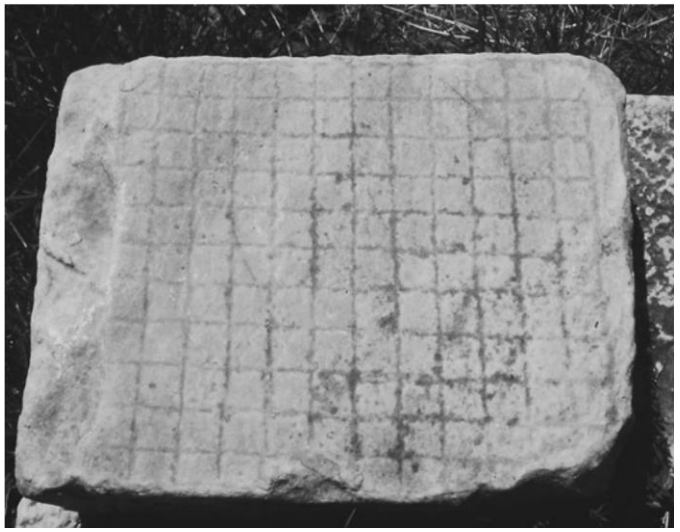
- Each game is associated with a suite of evidence: an **artifact**, **text**, **artistic depiction**, or **ethnographic observation**
- Some games will have many; others will have only one
- Evidence situates the game in a particular **time** and **place**
- Social data also important: **Age**, **Gender**, **Space**, **Social Class**

Documenting 58 Holes board at Campmalı, Azerbaijan

Case Study: Ludus Latrunculorum

- Four rules known:
  Square or rectangular board
- Orthogonal Moves
- Custodial Capture
- Placement Phase

6x7, Castro de Santa Tegra, Spain

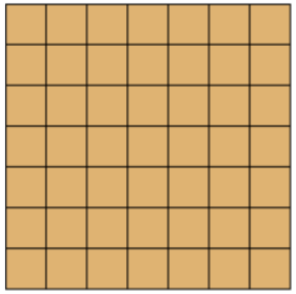


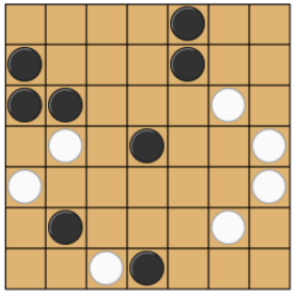
11x12, Temple of Hera, Samos, Greece

Candidate Rulesets

Kharebga (7x7) DLP Game

Leaderboard





Period Modern

Region Northern Africa

Category Board, War, Custodial

Description

Kharebga is a game with custodial captures played by children in El Oued, Algeria.

Rules

7x7 board. 24 pieces per player. Players alternate turns placing two pieces on an empty space on the board, except in the central space. Captures cannot be made during the placement phase. When all of the pieces have been placed, players alternate turns moving a piece orthogonally any distance. When an opponent's piece is between two of a player's pieces, it is captured. If a player is unable to make a move, they pass their turn and the opponent plays again. The player who captures all of the opponent's pieces wins.

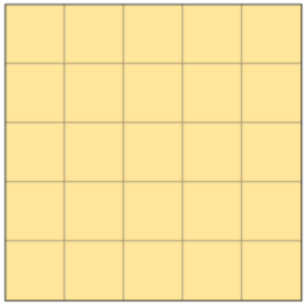
Bellin 1964: 53-54.

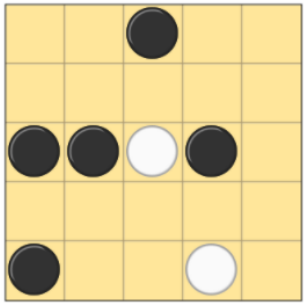
Origin

Algeria

Seega (*Siga, Sija, Seeja*) DLP Game

Leaderboard





Period Modern

Region Eastern Africa, Middle Africa, Northern Africa

Category Board, War, Custodial

Description

Seega is a game played in North Africa, and is particularly well-known in Egypt and Sudan. It is a game that is similar to Draughts or Alquerque, but has a custodial capture mechanism instead of leaping. It has been documented since the nineteenth century, but is likely to be older. The boards are typically scooped out of the sand or etched into stone surfaces.

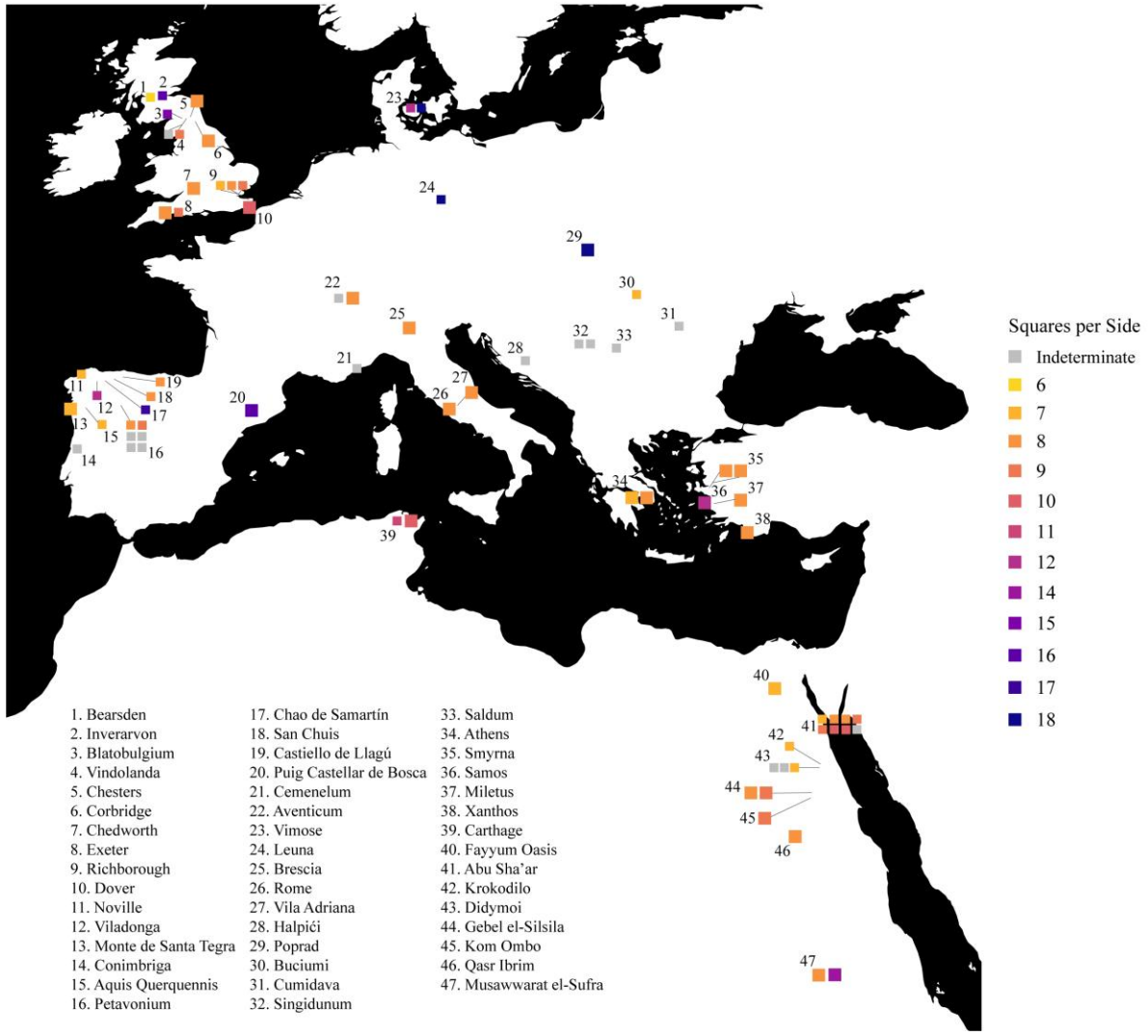
Rules

5x5 board. Players begin by placing their pieces in prescribed spaces, and then alternating two-by-two in places as they see fit, except for the central space. Once all the spaces except the central one are filled, the first player moves a piece one space orthogonally to the empty space. Pieces are captured by surrounding them on either side by a player's own pieces. The player to capture all of the opponent's pieces wins.

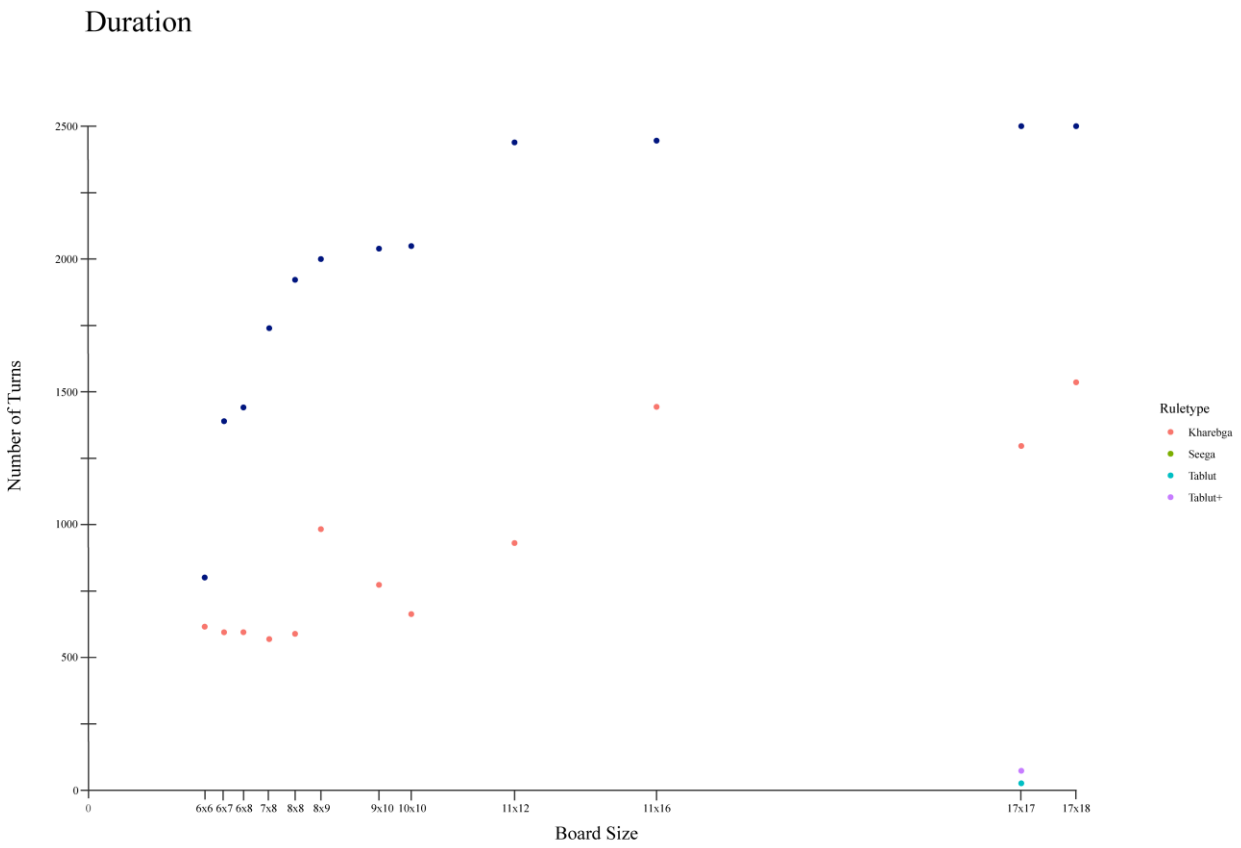
Lane 1836: 356-357; Davies 1925: 138-139; Bolton 190.

These rules were taken from the Khamsáwee ruleset.

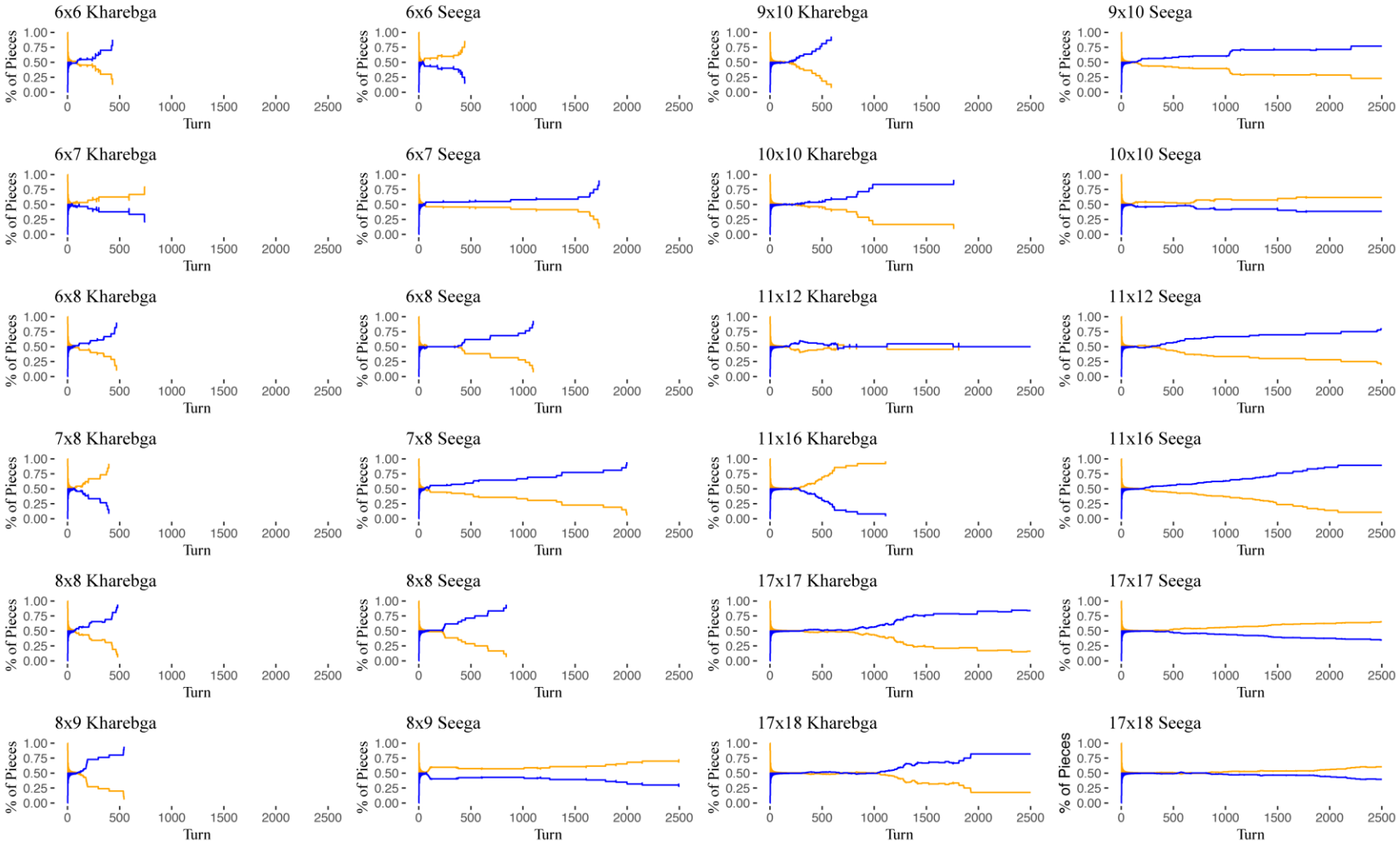
Quadrangular boards in and around the Roman Empire



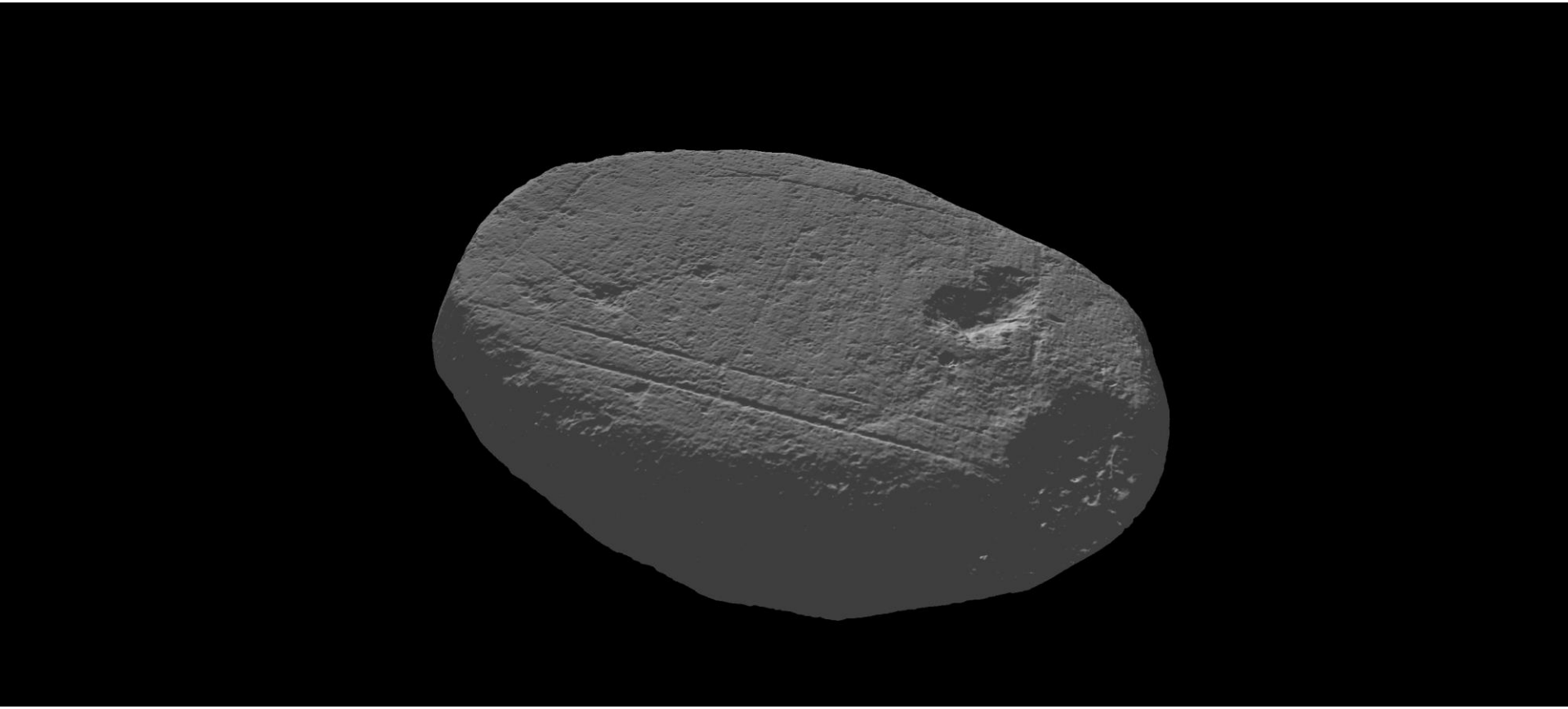
Length of Games



Percentage of Pieces on the Board per Player



“Thermenmuseum Game”



Matthew

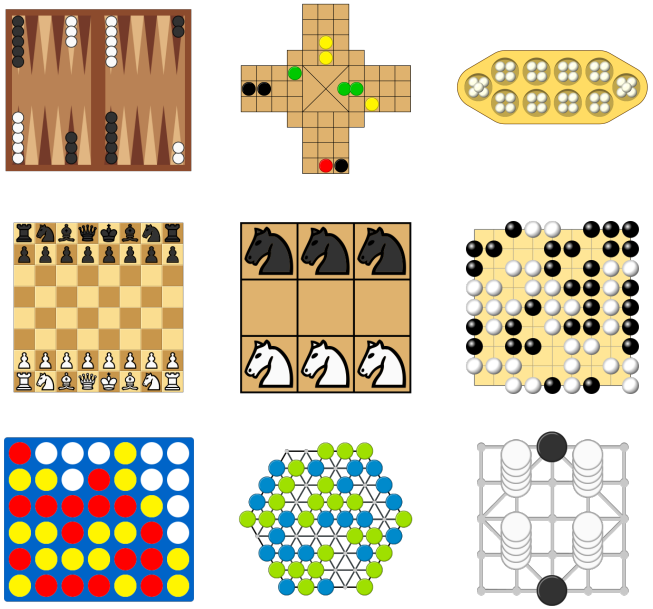
Data Mining

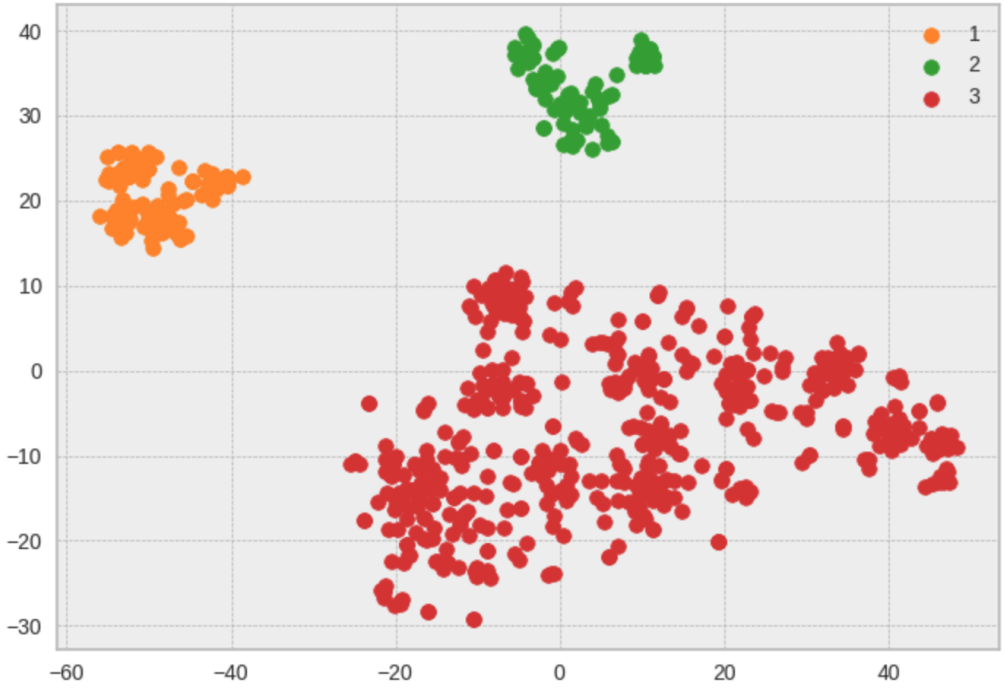
Lots of different datasets available:

- **Historical information** (period, location, culture)
- **Game concepts** (equipment, rules, visuals, math)
- **AI performance** (agents, heuristics, features)
- **Game Metrics** (bias, length, complexity)
- **User data** (most played game, online ratings)

Ludii Game Clusters

Group similar games together based on their concepts.





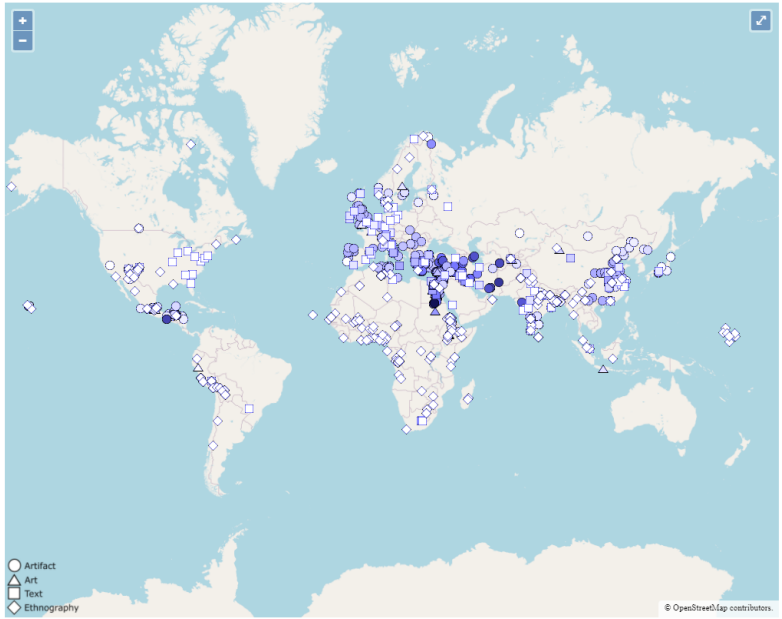
AI Performance Prediction

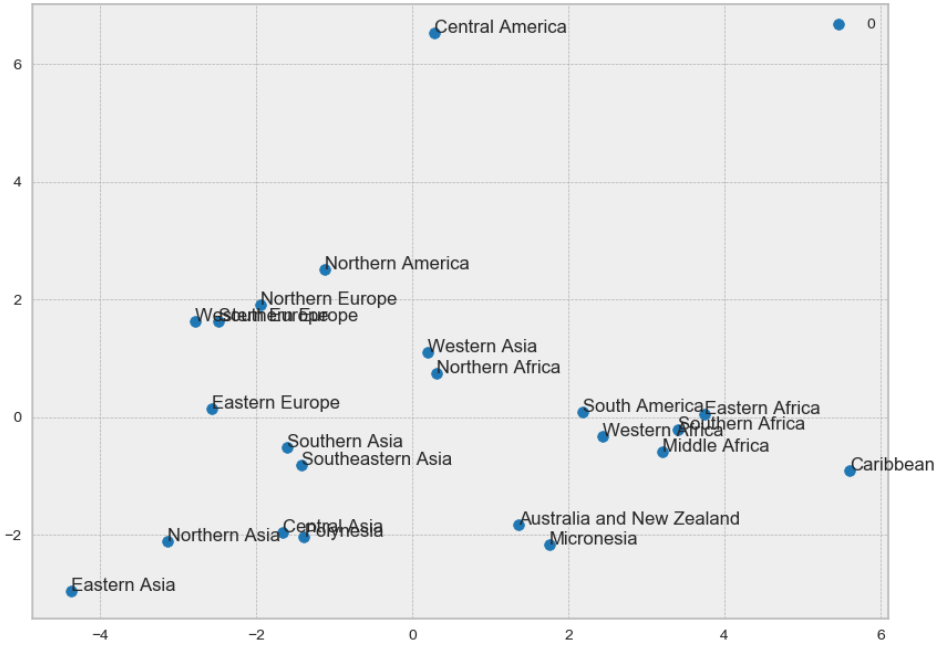
Use these clusters to predict how AI agents or heuristics will perform.

Regression Algorithm	MAE (stdev)	Win-Rate	Regret
RandomForestRegressor	7.48 (1.28)	71.03%	7.68
GradientBoostingRegressor	7.87 (1.54)	70.83%	7.88
KNeighborsRegressor	8.05 (1.39)	70.46%	8.25
BayesianRidge	8.29 (1.50)	70.26%	8.45
LinearSVR	8.56 (1.31)	69.97%	8.74
MLPRegressor	8.90 (1.40)	70.15%	8.56
ElasticNet	9.13 (1.83)	67.92%	10.79
Lasso	9.26 (1.81)	67.63%	11.08
Ridge	9.50 (1.76)	68.86%	9.85
DecisionTreeRegressor	9.70 (1.61)	67.95%	10.76
Naive	10.07 (2.58)	62.09%	16.62

Ludii Game Clusters

Detect game similarities between different regions.





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Game Distance

Measure the distance between two games.

- How close are the game's cultures?
- Do they have similar rules and mechanisms?
- Are the same playing strategies effective?
- Did one of these games influence the other?

Use this distance measure to help with game reconstruction.

Game Reconstruction

- Games which are closer are more likely to share concepts.
  - Equipment
  - Rules
  - Gameplay

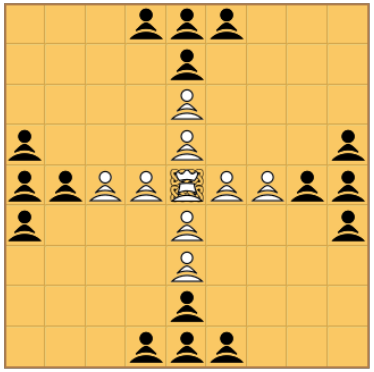
- When reconstructing games, we can take inspiration from other nearby games.

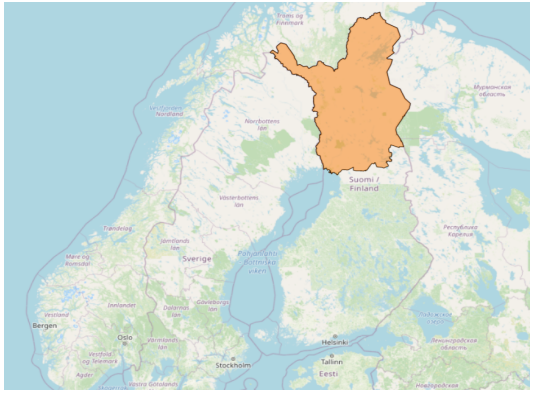
Example

- Use rules of Tablut as a basis for reconstructing other Tafl games.

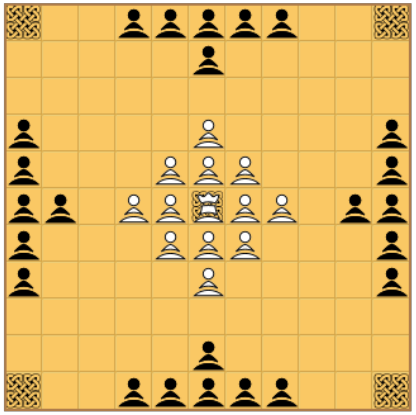
- Similar time and place.
- Similar board design.

- Probably similar rules.





Tablut (1732CE)



Hnefatafl (790 - 1413CE)

Future Ideas

Game Recommender:

- Recommend games to Ludii users based on their ratings.

Game Evaluator:

- Evaluate new games created by designers for flaws.

Game Chronology:

- Show how games traveled between cultures.
- Show how a game’s rules evolved over time.

Demo

Overview of a Game description

```
(game "Amazons"
    (players 2)

    (equipment {
        (board (square 10))
        (piece "Queen" Each (move Slide (then (moveAgain))))
        (piece "Dot" Neutral)
    })
    (rules

        (start {
            (place "Queen1" {"A4" "D1" "G1" "J4"})
            (place "Queen2" {"A7" "D10" "G10" "J7"})
        })

        (play
            (if (is Even (count Moves))
                (forEach Piece)
                (move Shoot (piece "Dot0"))
            )
        )

        (end (if (no Moves Next)(result Mover Win)))
    )
)
```

Number of players

Equipment:
Containers, Components, …

Starting Rules:
Piece placement, initial score, …

Playing Rules:
Legal moves for each state

Ending Rules:
Terminal conditions and outcomes

Conclusion

Thank You

Questions?

http://ludeme.eu

http://ludii.games

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