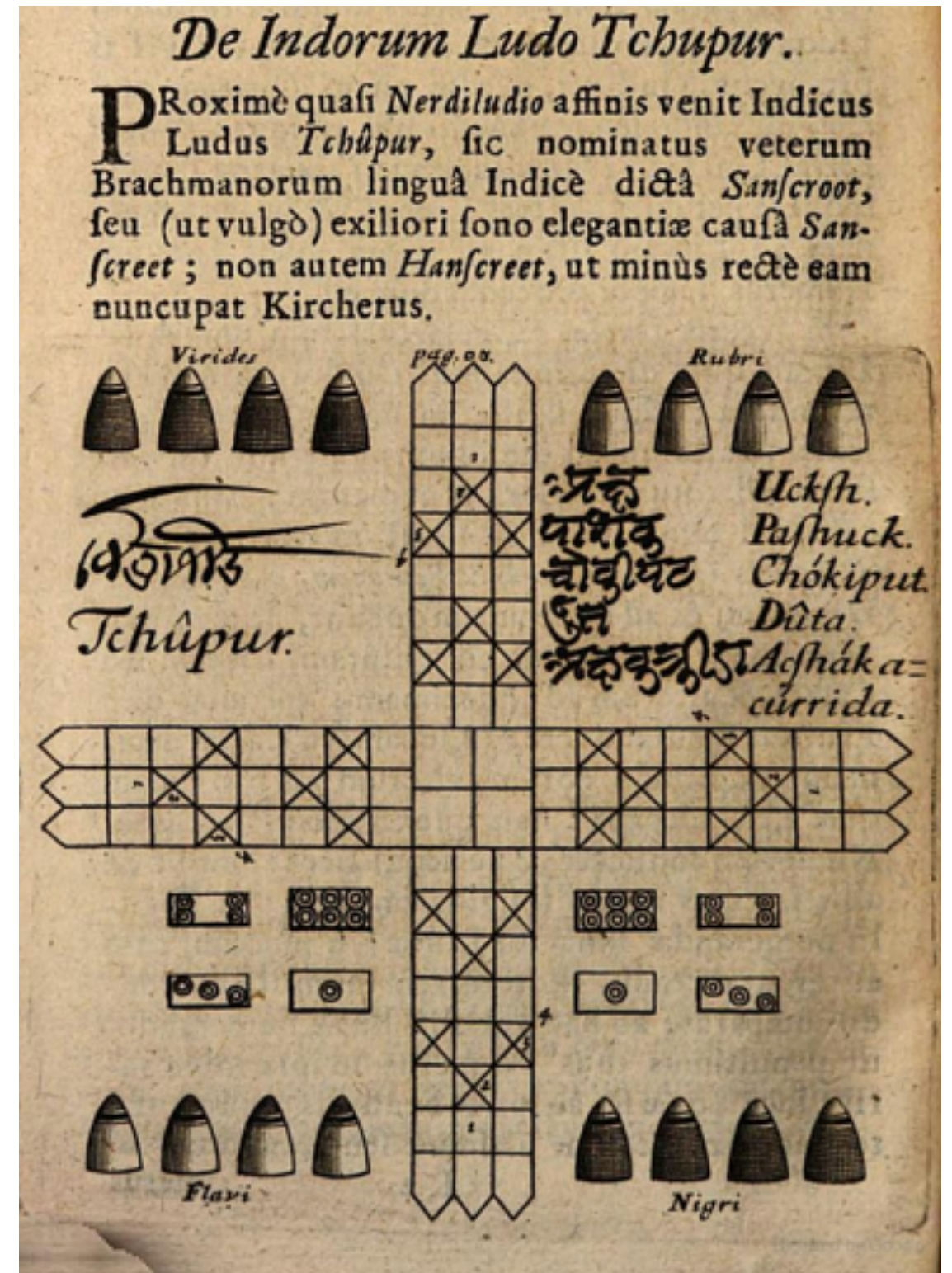


Games and Artificial Intelligence:

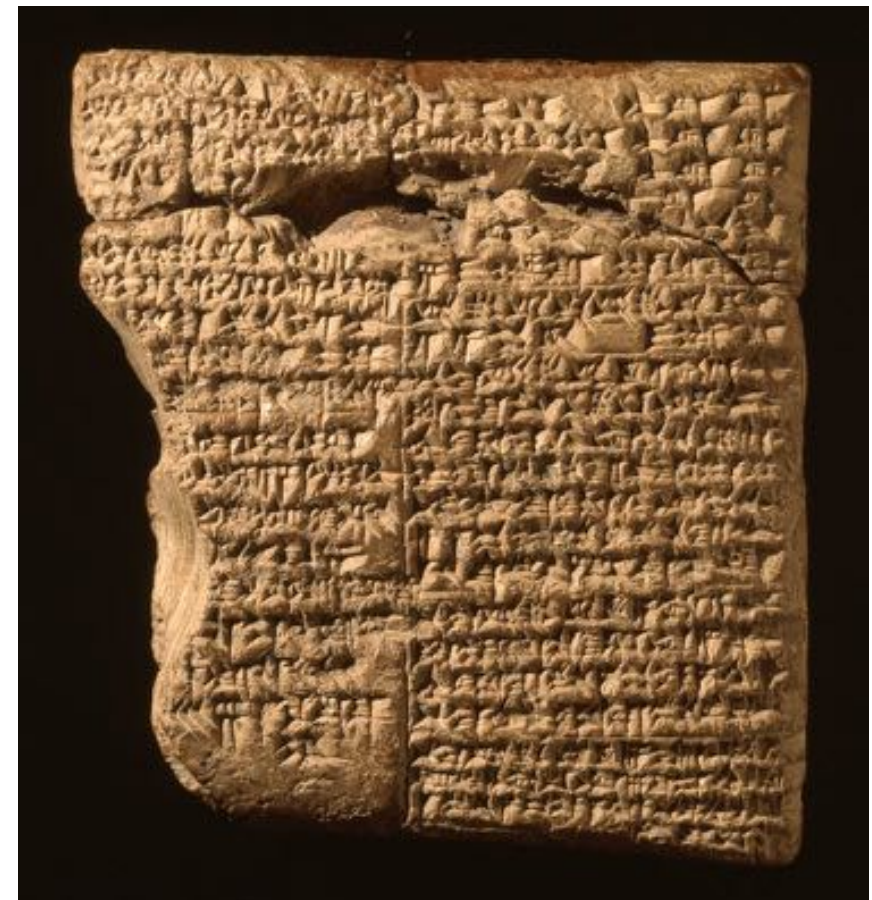
Reconstructing and Playing Ancient Games

Walter Crist
Maastricht University
INSTUCEN Virtual Talk
August 8, 2020



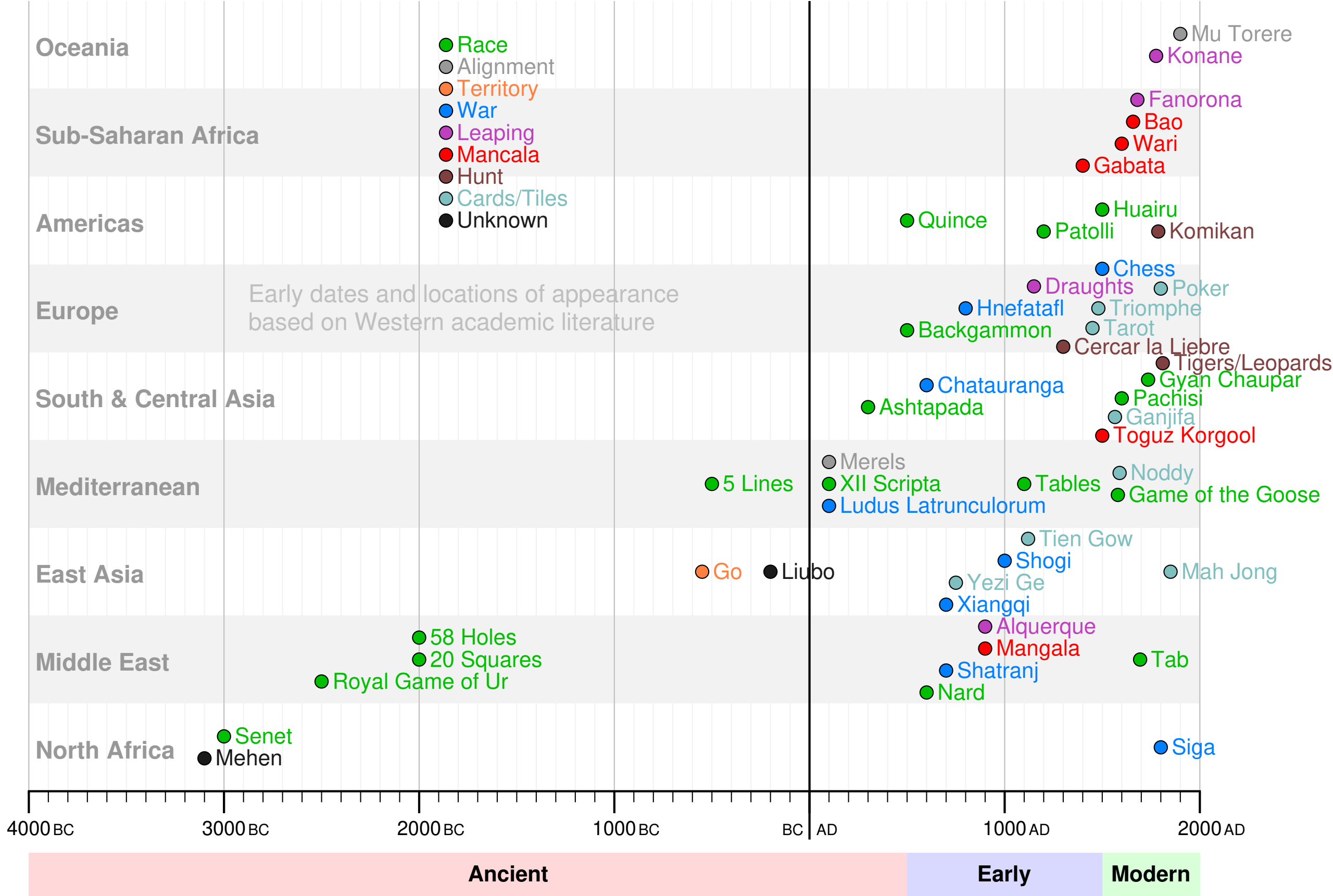
Games In Human History

- ~5000 years of documented history of games (maybe ~9000 years)
- Games are found worldwide, among all types of societies
- Most people did not write down rule sets!
- Archaeological evidence provides clues
- Reconstruction of ancient games has been a subjective endeavor



Seleucid Game Rules text, British Museum. Ur, Iraq, 177 BCE. BM 33333

Timeline



Games in Anthropology and Archaeology

- Documentation of rules
- Attempts to trace origins
- Cultural diffusion



**Patolli, 16th cent.
Mexico (Florentine Codex)**



**Pachisi, 18th cent.
North India (after Finkel 2006: Fig. 4)**

Archaeology and Games

- New approaches in archaeology favor scientific techniques and emphasis on social processes
- Lack of evidence
- Lack of available anthropological theory
- De-emphasis of cultural diffusion
- Little work done, except for culturally-specific research



**Tomb of Tutankhamun,
Photograph: Harry Burton,
1922**

Rebooting Old Goals: The Digital Ludeme Project

- 5 year ERC funded research project led by Cameron Browne
- Using the available historical evidence, use Artificial Intelligence (AI) to:
 - **Model** and preserve the knowledge of games from the past
 - **Reconstruct** missing knowledge
 - **Map** transmission of games



Project Team

- **Cameron Browne:** Project lead
 - Game AI
- **Éric Piette:**
 - Game AI (Game engine development)
- **Matthew Stephenson**
 - Game AI (User interface, networking, data mining)
- **Walter Crist**
 - Archaeologist (Historical and cultural content)
- **Dennis Soemers**
 - Game AI (Feature learning)

How is this different?

- Evidence-based: Primary sources
- Reconstructions provide new lines of evidence, previously inaccessible
- Scientific and quantitative in approach
- Critically evaluates games reconstructions for historical accuracy



Royal Game of Ur, British Museum, c. 2600 BCE. BM 120834.

1000 “Most Important” Games

- What does “important” mean?
- Criteria include:
 - Documented in some form
 - Can be given a geographic location and time range
 - Were not commercially invented for sale
 - Involve more than just chance
 - Exceptions for historically significant games: Gyan Chaupar, Game of the Goose
- Includes board, card, and domino games



Nine Men's Morris, Roman period, Musée Nationale d'Histoire et d'Art, Luxembourg.



Liubo set from China, 1st century BCE–1st century CE. Metropolitan Museum of Art 1994.285a–m.

Ludemic Game Description

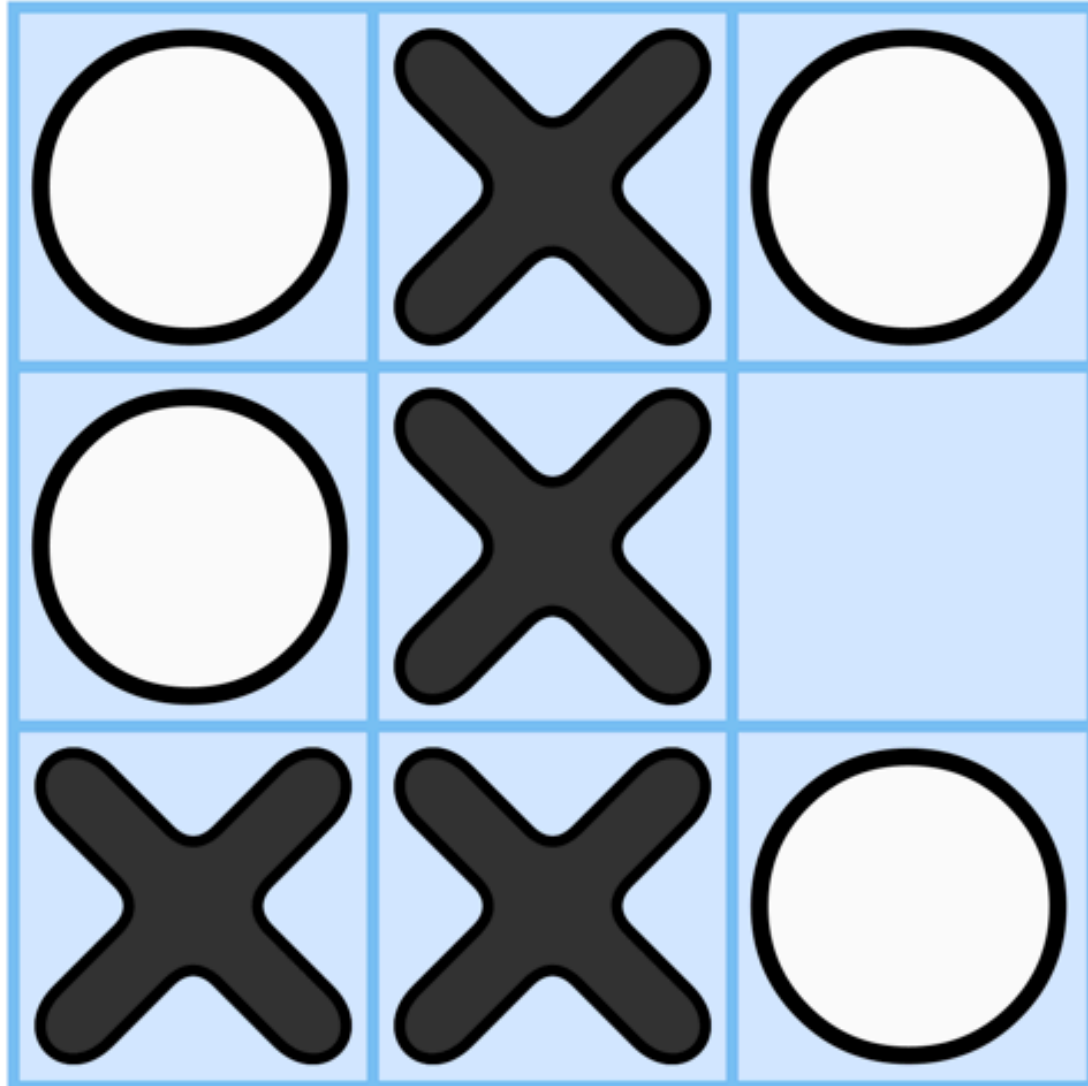
- “Ludeme”: game “meme”
- Much simpler than the industry standard game programming language (Game Description Language)
- Human readable: more closely reflects the ways humans conceptualize games

```
(tiling square)
```

```
(size 3 3)
```

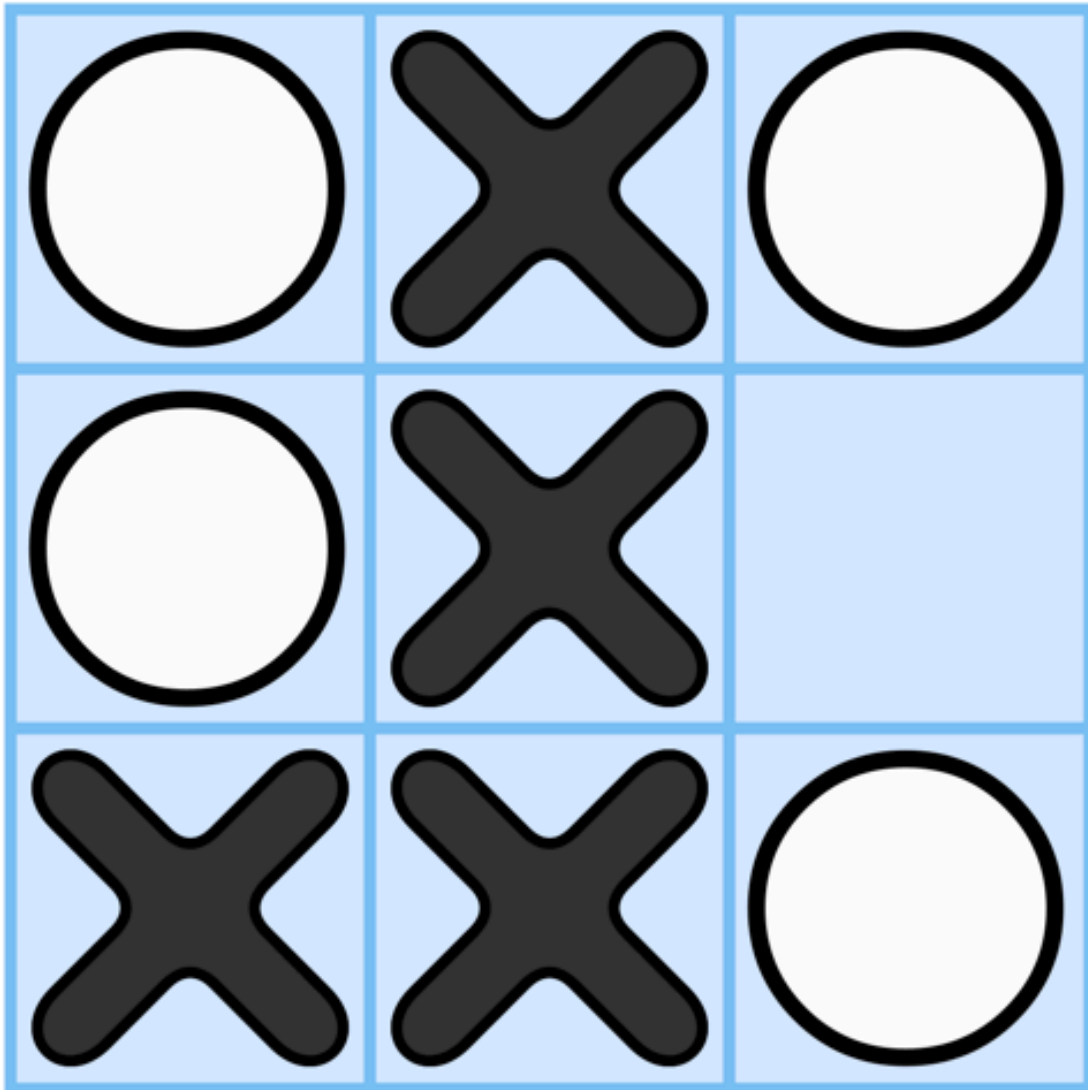
```
(board  
  (tiling square)  
  (shape square)  
  (size 3 3)  
)
```

Game Description Language



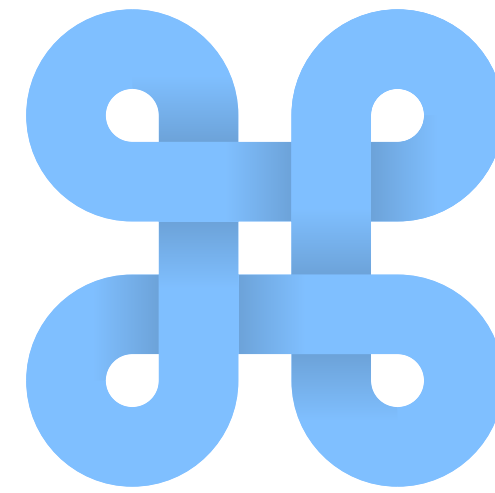
```
(role white) (role black)
(init (cell 1 1 b)) (init (cell 1 2 b)) (init (cell 1 3 b))
(init (cell 2 1 b)) (init (cell 2 2 b)) (init (cell 2 3 b))
(init (cell 3 1 b)) (init (cell 3 2 b)) (init (cell 3 3 b))
(init (control white))
(<= (legal ?w (mark ?x ?y)) (true (cell ?x ?y b))
  (true (control ?w)))
(<= (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))
```


Ludemic Language

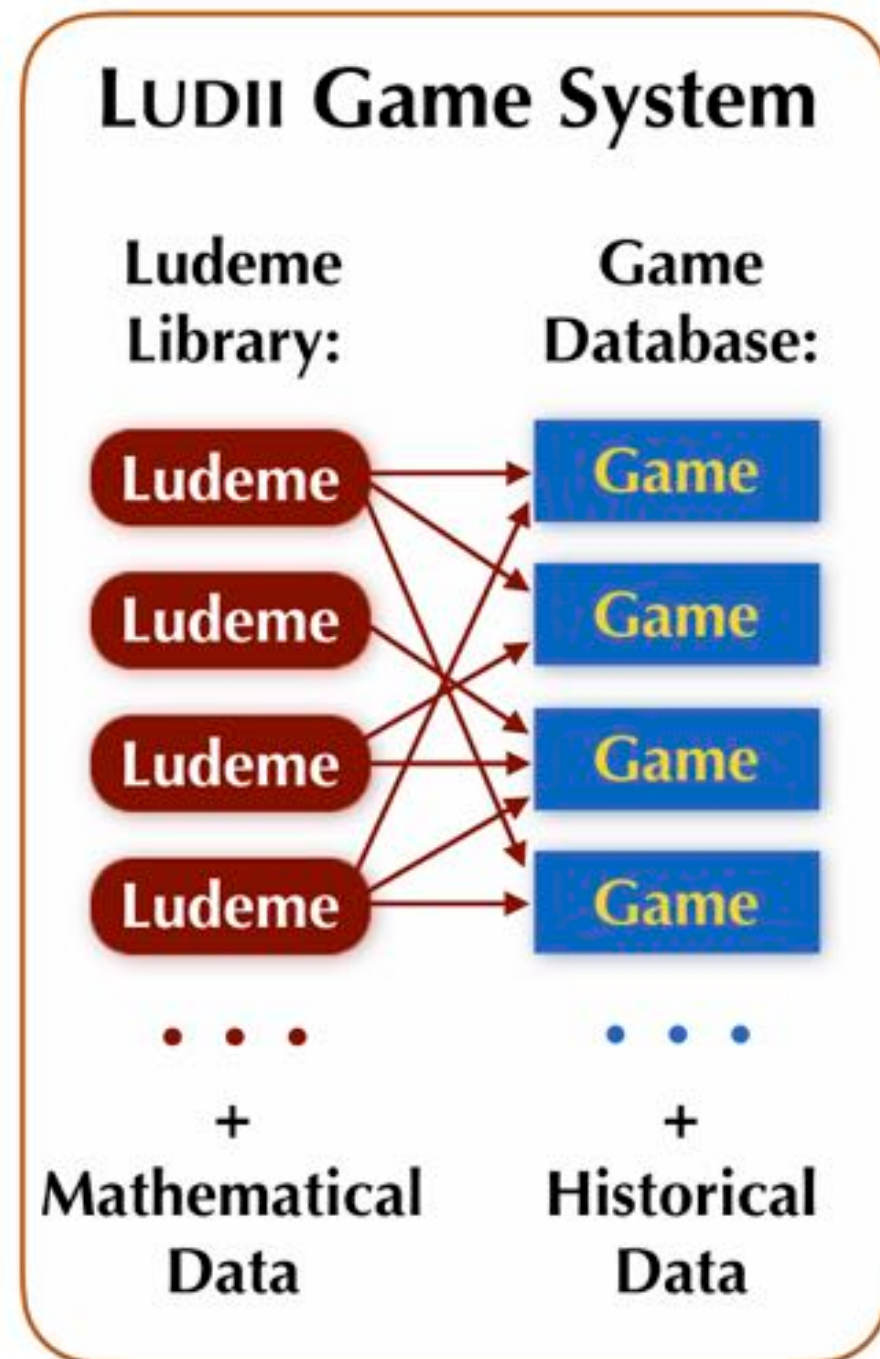


```
(game Tic-Tac-Toe
  (players White Black)
  (board
    (tiling square)
    (shape square)
    (size 3 3)
  )
  (end (All win (in-a-row 3)))
)
```

Ludii

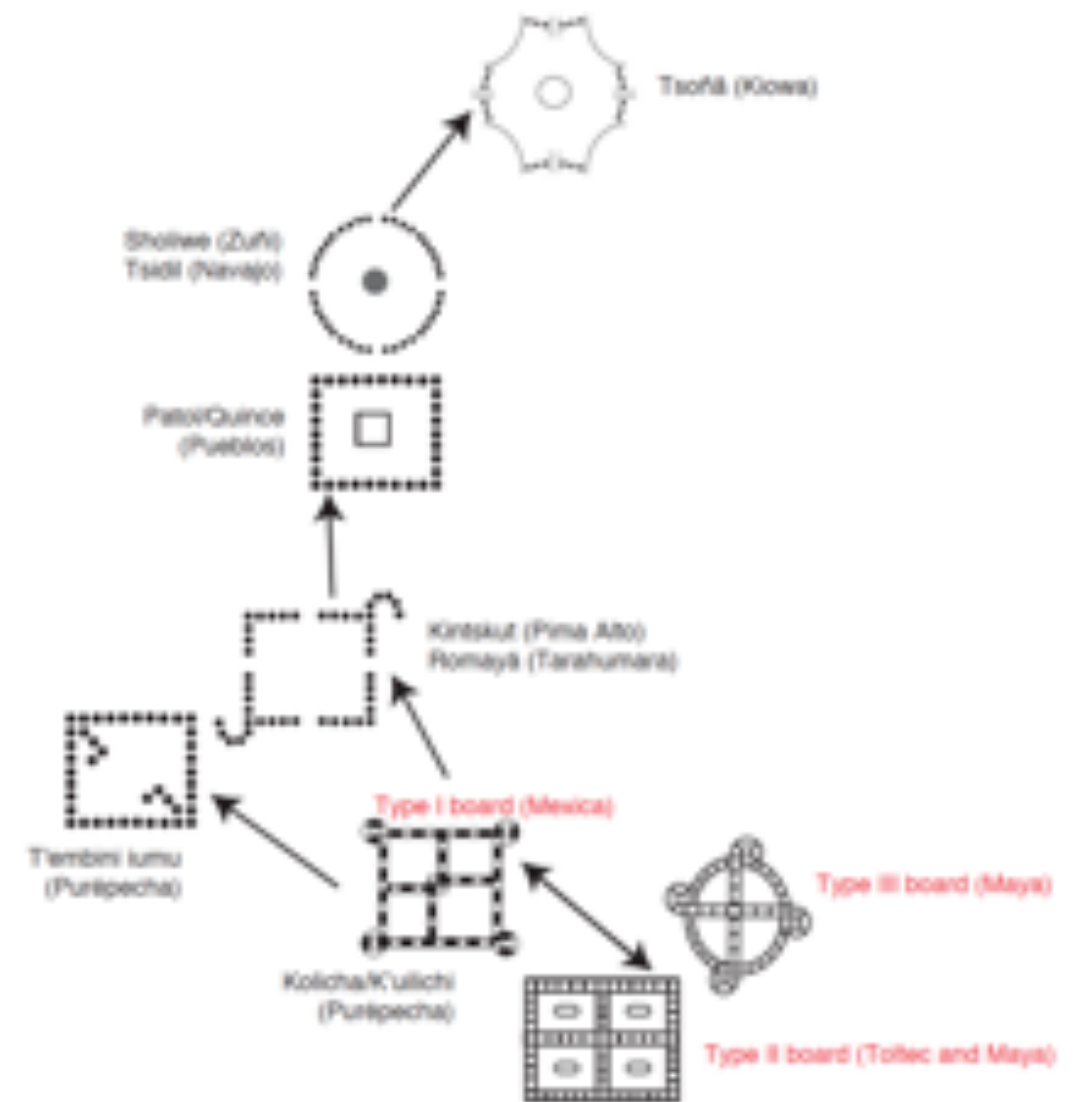


- General Game System based on:
 - Ludeme Library
 - Game Database
 - Game Descriptions
 - Historical Data
- Games are playable!
ludii.games



Historical Game Reconstruction

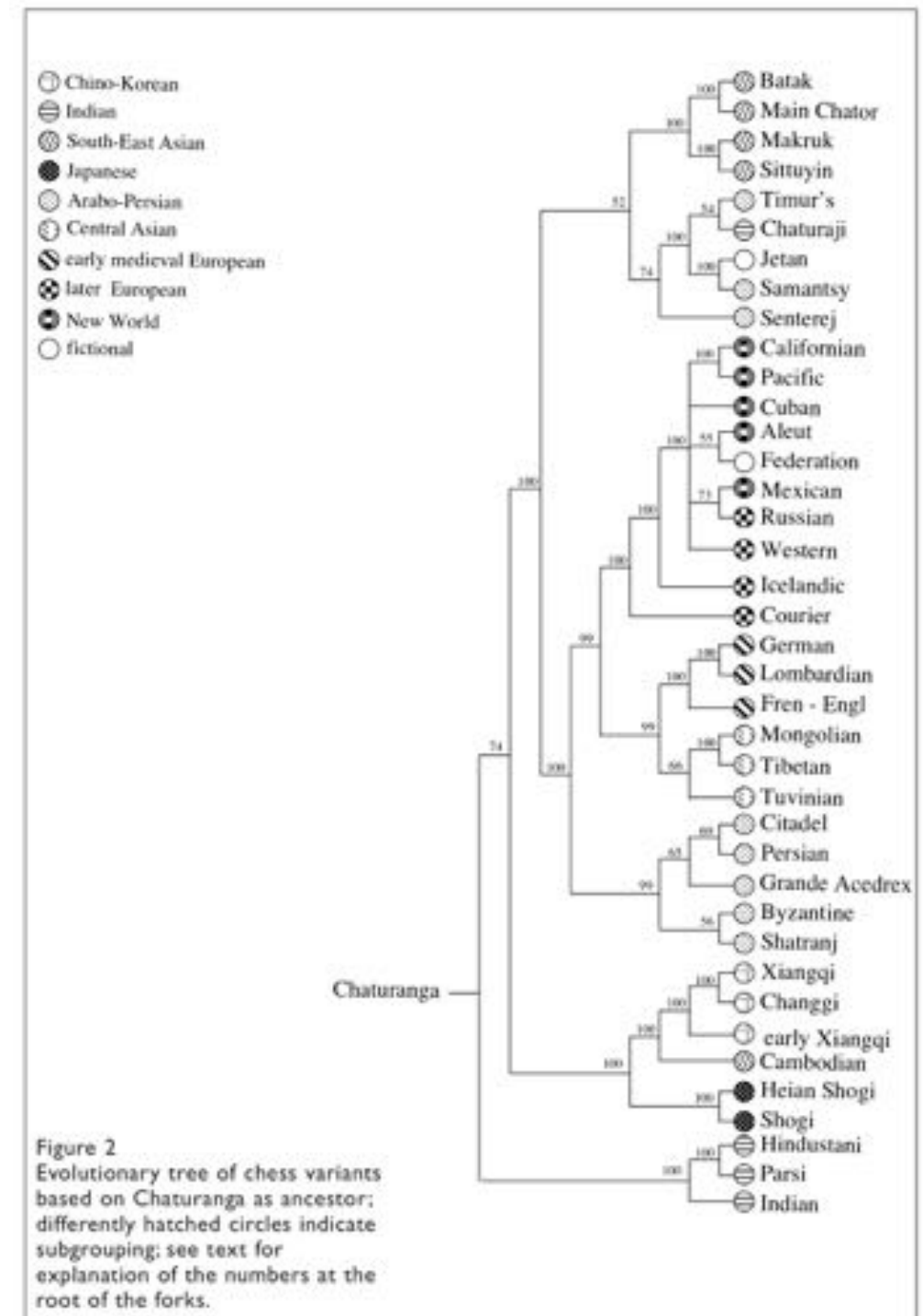
- Cultural Transmission Theory explains how games are transferred from person to person
- Ludemes are the packages which are transmitted (DNA of games)
- Need to calculate ludemic distance: number of steps required to change one game into another



Evolution of North American and Mesoamerican board games (after Depaulis 2018)

Computational Phylogenetics

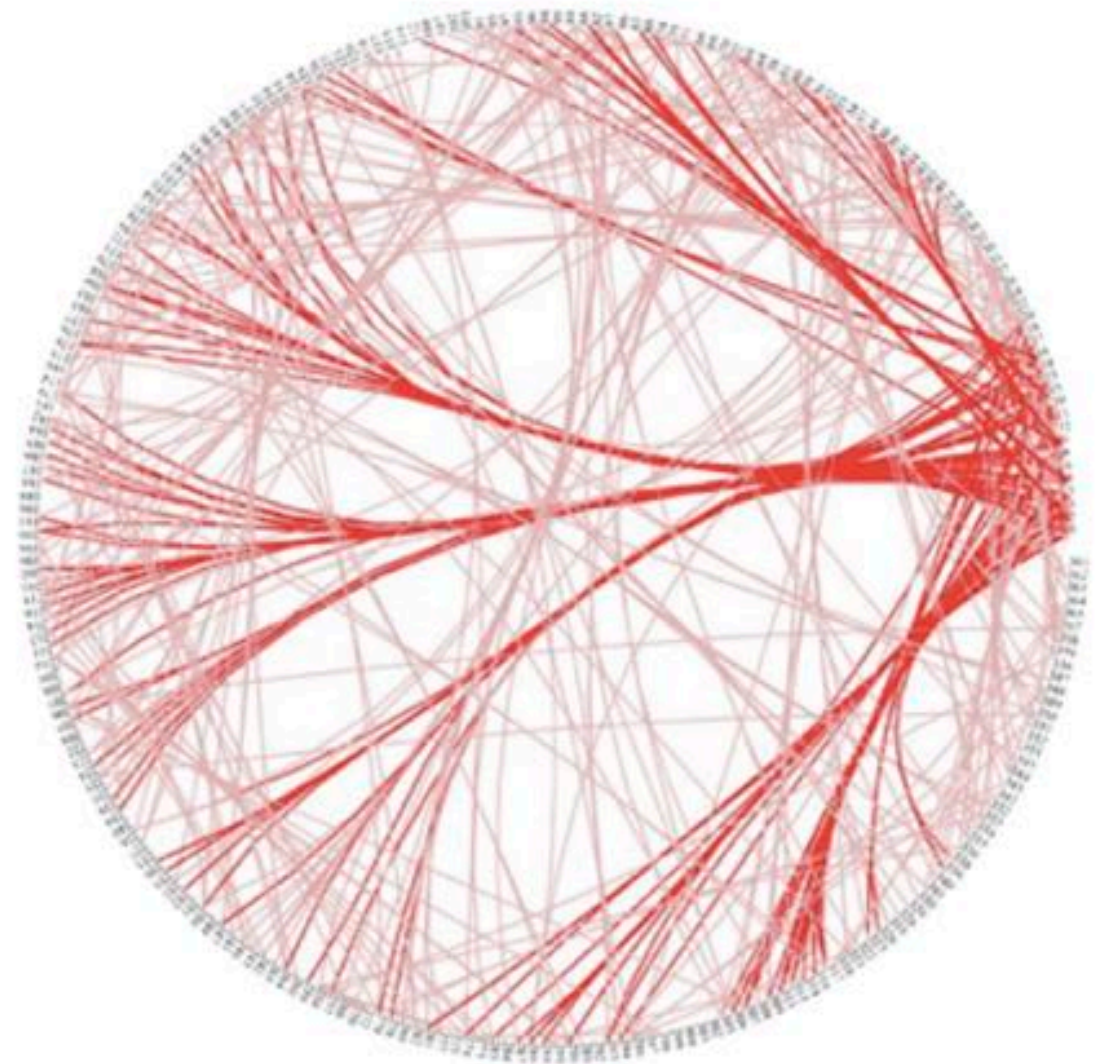
- Developed from biology
- Measures evolutionary relationships between entities
- Has been used in linguistics, but also for games in the past
- Can help to determine which games likely developed from others



Kraaijeveld 2000.

Horizontal Transmission

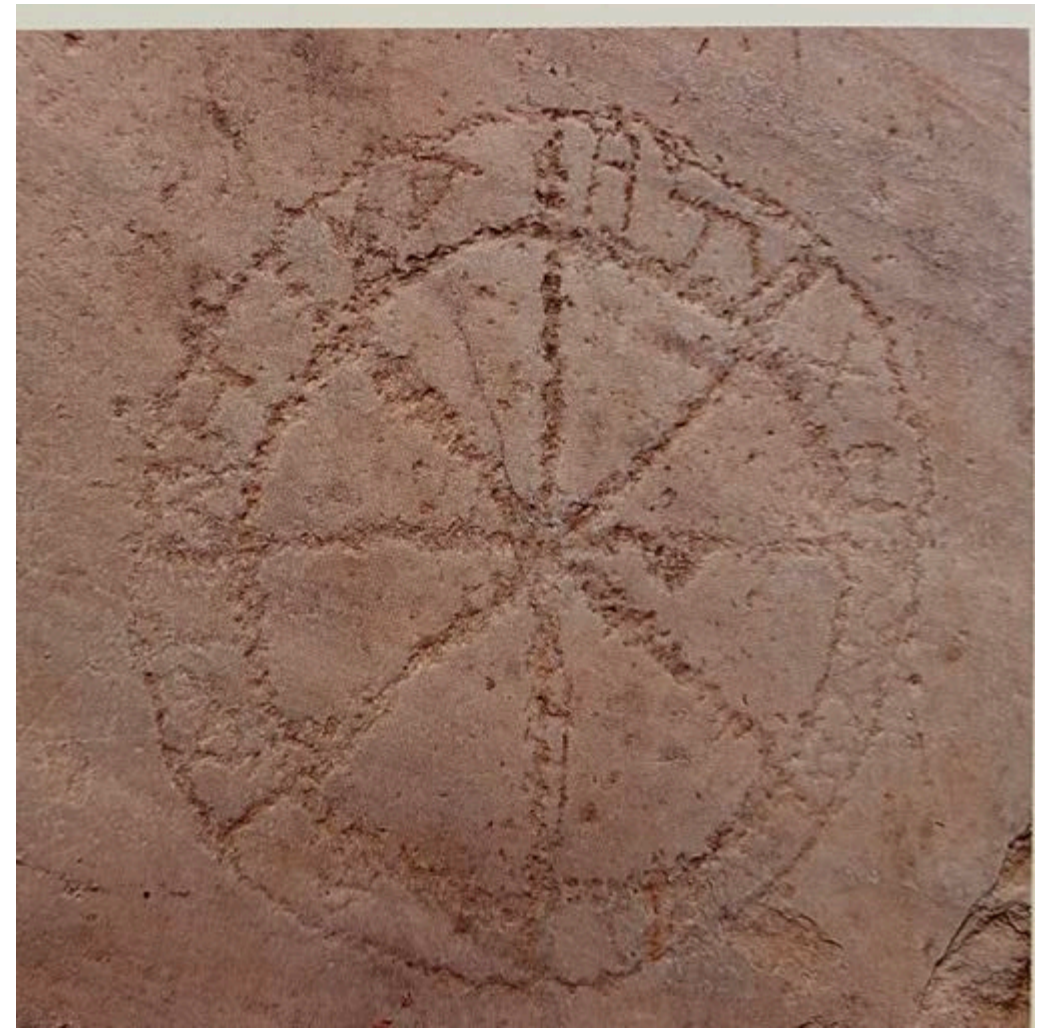
- Games are transferred through horizontal transmission
- Requires different conceptualization of transmission and modeling
- Allows a better reconstruction of ludic transfer



HIM of programming languages
Valverde & Sole (2015) *JRSI*

Challenges for Historical Reconstruction

- Data are sparse and missing information
- Multiple lines of evidence
- Some pieces are less reliable for providing certain kinds of information
 - Historical sources writing about games in their past
 - Uncertainty whether certain artifacts belong to certain games
- Much information that exists is speculation



“Round Merels” pattern from Ephesus, Turkey. (after Schädler 2012.)

Evidence-based Historical Data

- Each game is associated with a suite of pieces of “evidence”: an artifact, text, depiction, ethnographic observation. which provides some clue about the rules of the game
- Some games will have many; some will have only one
- Evidence supports the connection between ludemes and particular games.
- Uncertainty factors assigned to each piece of evidence



Documenting 58 Holes board at Capmalı,
Azerbaijan, April 2018

Data to be gathered

- Name
- Location
- Game rules
- Social status
- Gender of players
- Age of players
- Spaces in which people played



Game boards from Sotira *Kaminoudhia*, Cyprus

Artifacts

- Actual materials used to play: board
- Tell us about:
 - Date
 - Location
 - Form of the board
 - Markings on the board
 - Gaming equipment
 - Sometimes: Social status; gender; space



Senet board from Tomb of Tutankhamun



**Senet fragment in Arizona State Museum;
c. 980–838 BCE (after Romano et al 2018)**

Textual Evidence

- Primary texts that mention a game or discusses its rules
- Tells us about:
 - Rules
 - Gaming equipment
 - Location
 - Date
 - Sometimes: Social status; gender; spaces



Page from Alfonso X of Castille's *Libro de los Juegos*, 1283

Ugallu-bird, a pill token;

Raven, a pill token;

Eagle, a pill token;

Swallow, a pill token;

Rooster, a pill token; Five flying game pieces.

An ox astragal, a sheep astragal,

Two that move the game pieces.

If the astragals score 2, the Swallow sits at the head rosette.

Should it then land on a rosette, a woman will love those who linger in a tavern, well-being is established for their pack.

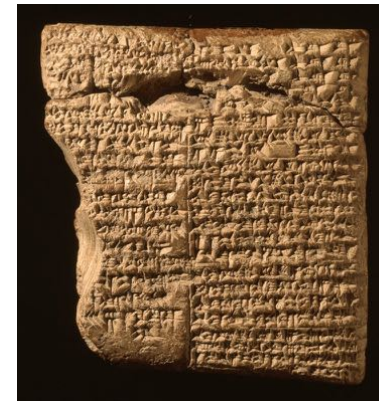
If it does not land on a rosette, a woman will reject those who linger in a tavern, well-being is not established for the entire pack....

Written, checked, and examined. Tablet of Iddin-Bel, son of Maranu.

By the hand of Itti-Marduk-balatu II.

He who fears Bel and Beltiya, and Nanaya of Ezida, must not efface the writing!

Babylon; Month of Arahsamna, Day 3, Year 135 of Seleucus the King.



Seleucid Game Rules
text, British Museum.
177 BCE. BM 33333



20 Squares board from Enkomi,
Cyprus, 13th century BCE. BM
1897,0401.96

how a multi-coloured piece attacks in a straight line,
when a piece between two enemy pieces is lost,
how to pursue with force, and then recall
the piece in front, and retreat again safely, in company

Ovid, *Tristia* 2.477–480

at one time a white counter traps blacks, another a black traps whites; Yet what counter
has not fled from you; another, which stood at a vantage point, comes from a position far
retired; each of your hands rattles with its band of captives

Anonymous, *Laus Pisonis* 192–208

two sets of lines are drawn up, the ones crosswise and the others vertical, as is the regular
arrangement on a board on which they play *latrunculi*.

Varro, *De lingua latina* 22

She should play the *latrunculus* game warily not rashly, where one piece can be lost to
twin enemies, and a warrior battles without his companion who's been taken, and a rival
often has to retrace the journey he began

Ovid, *Ars Amatoria* 3.356–60

So you win, with a *mandra*, and the glass *latrones* are closed off

Martial, *Epigrams* 7.72.7–8

He was playing at *latrunculi* when the centurion in charge of a number of those who were
going to be executed bade him, join them: on the summons he counted his men and said
to his companion, "Mind you do not tell a lie after my death, and say that you won;" then,
turning to the centurion, he said "You will bear me witness that I am one man ahead of
him." Do you think that Kanus played upon that game board? nay, he played with it.

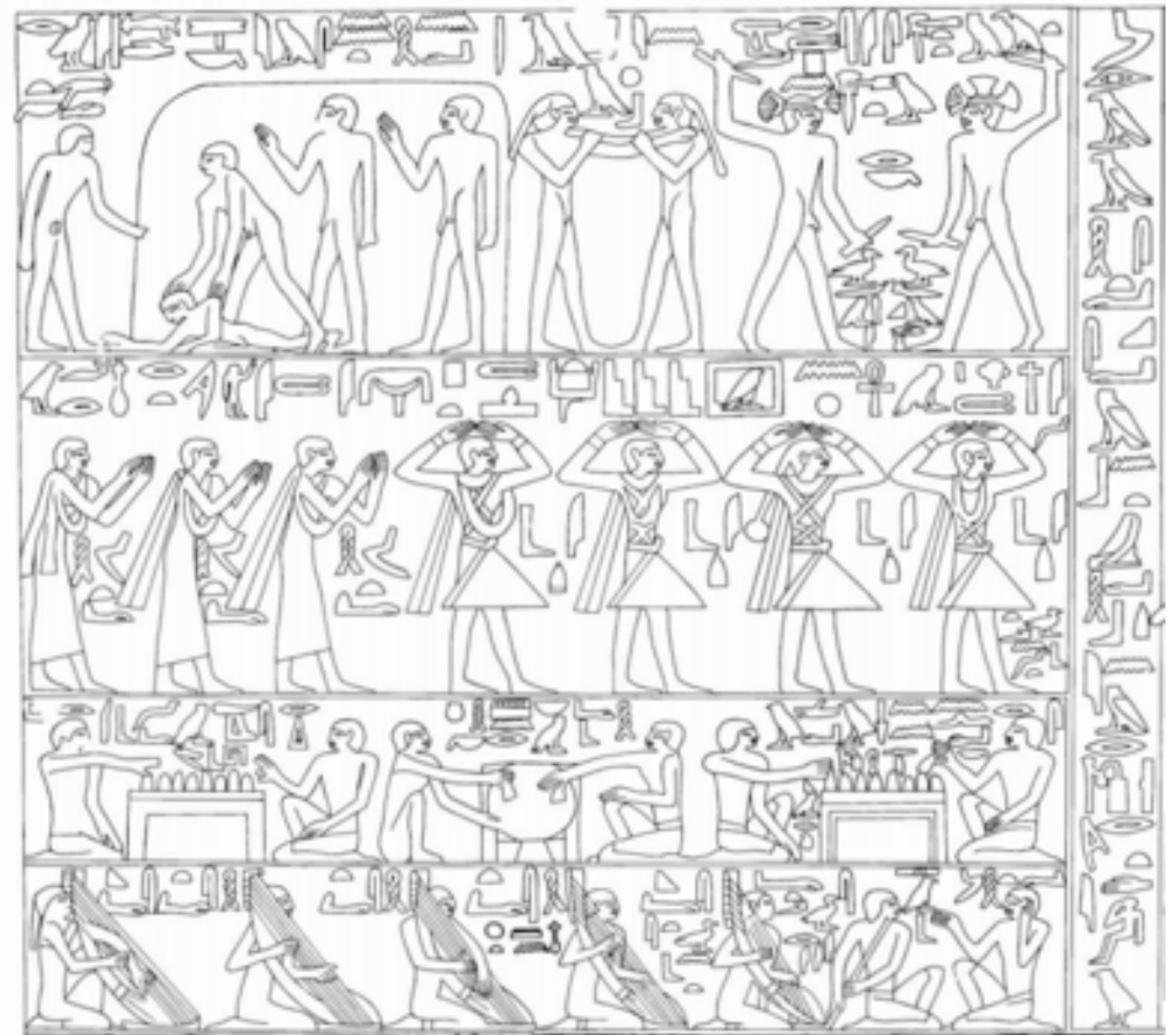
Seneca, *De Tranquillitate Animi* 14.7



***Ludus Latrunculorum* Board,
Segedunum, England**

Artistic Depiction

- Scenes of people playing games
- Tells us about:
 - Social context
 - Social status
 - Gender
 - Gaming equipment
 - Sometimes: form of the board; snippets of game action; space



Relief from the Tomb of Idu, Gaza, Egypt, 2345-2181 BCE.
(after Simpson 1976).



***Filles turques qui jouent au Mangala,
Jean-Baptiste Vanmour, 1714***



Sailors playing game, Tomb of Nefwa, Beni Hasan, Egypt, 2125–1940 BCE (after May 1991).

Ethnography

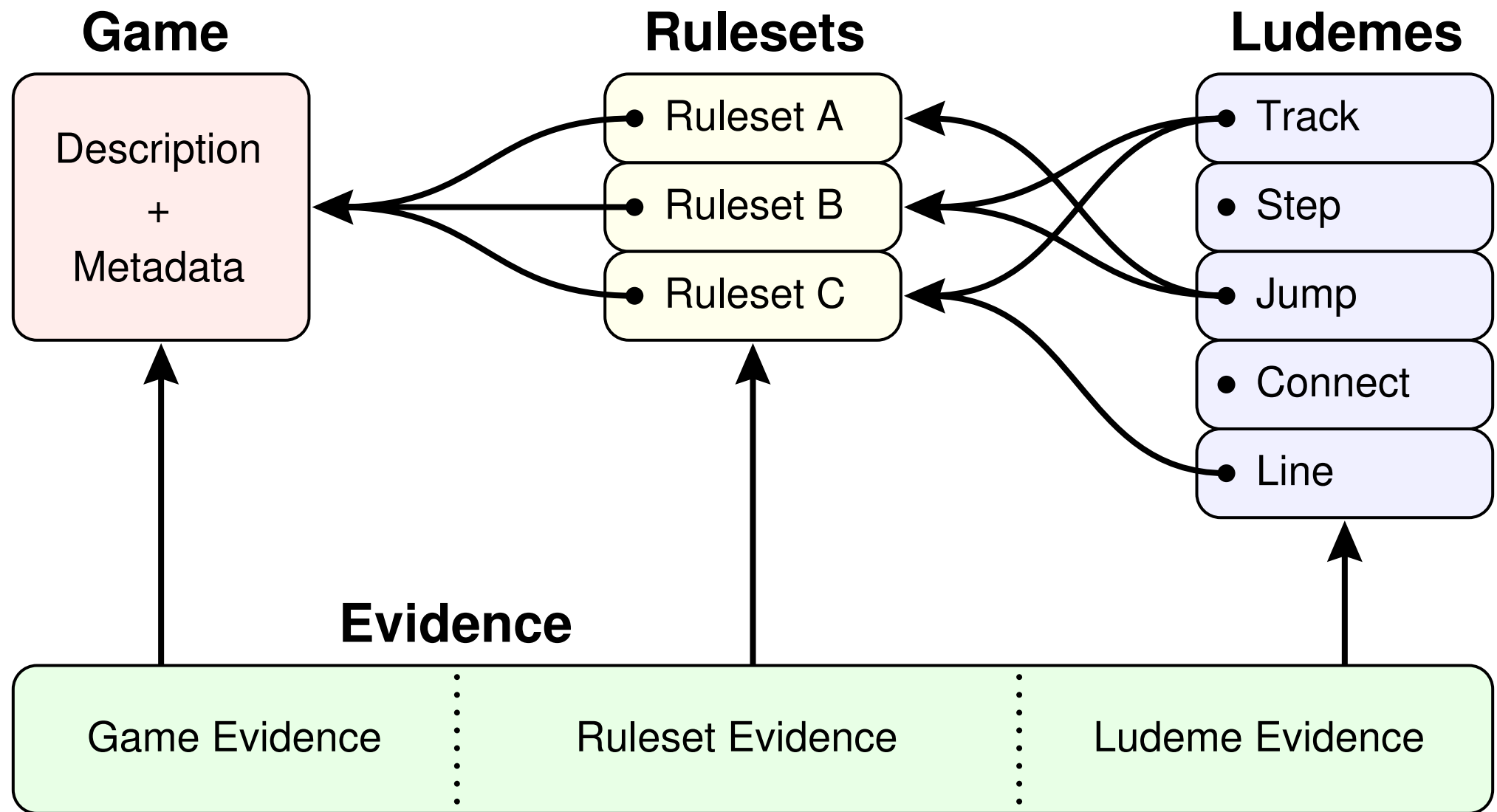
- Observation and documentation of people actually playing games
- Tells us about:
 - Gender
 - Gaming Equipment
 - Social Status
 - Age
 - Spaces
 - Location
 - Date
 - Sometimes: Rules, history



Alquerque players in Comoros (after de Voogt 2019).

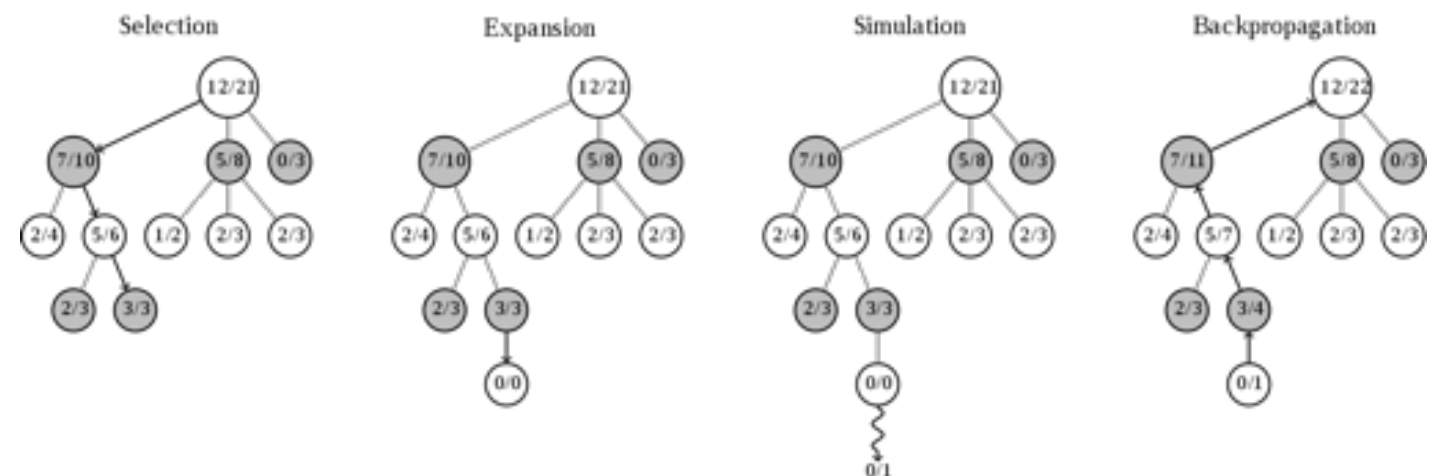
"The Penihings have a game called ot-tjin which I also observed in other Bornean tribes, and which to some extent is practiced by the Malays...With the Penihings the complete name is aw-li on-nam ot-tjin, meaning: play on-nam fish. An essential of the game is an oblong block of heavy wood which on its upper surface is provided with two rows of shallow holes, ten in each row, also a larger one on each end. The implement is called tu-tung ot-jin, as is also both of the single holes at the ends. There are two players who sit opposite each other, each controlling ten holes. The stake may be ten or twenty wristlets, or perhaps a fowl, or the black rings that are tied about the upper part of the calf of the leg, but not money, because usually there is none about. The game is played in the evenings. Two, three, four, or five stones of a small fruit may be put in each hole; I noticed they generally had three; pebbles may be used instead. Let us suppose two have been placed in each hole; the first player takes up two from any hole on his side. He then deposits one in the hole next following. Thus we have three in each of these two holes. He takes all three from the last hole and deposits one in each of the next three holes; from the last hole he again takes all three, depositing one in each of the next three holes. His endeavour is to get two stones in a hole and thus make a "fish." He proceeds until he reaches an empty hole, when a situation has arisen which is called a gok—that is to say, he must stop, leaving his stone there. His adversary now begins on his side wherever he likes, proceeding in the same way, from right to left, until he reaches an empty hole, which makes him gok, and he has to stop. To bring together two stones in one hole makes a "fish," but if three stones were originally placed in each hole, then they make a "fish"; if four were originally placed, then four make a "fish," etc., up to five. The player deposits the "fish" he gains to the right in the single hole at the end. The two men proceed alternately in this manner, trying to make a "fish" (ára ot-tjin). The player is stopped in his quest by an empty hole; there he deposits his last stone and his adversary begins. During the process of taking up and laying down the stones no hole is omitted, in some of them the stones will accumulate. On the occasion of the game i described I saw two with eight in them. When one of the players has no stones left in his holes he has lost. If stones are left on either side, then there is an impasse, and the game must be played over again."

Lumholtz, C. 1920. *Through Central Borneo: An Account of Two Years' Travel in the Land of the Head-Hunters between the years 1913 and 1917*. Stockholm.



Artificial Intelligence

- Evaluates potential game states
- Chooses moves based on evaluations
- Provides basis for analysis of reconstructions



Probabilistic Reconstructions

- Define constraints: Based on evidence, what can be determined for certain about game rules
- Possible ludemes that fill in the gaps of knowledge will be used to run simulations of games using Artificial Intelligence
- Games will be scored based on their playability, based on measures of:
 - Drawishness
 - Elimination of endless loops
 - Playing time
 - Bias
- Maximize possible reconstructions for historical accuracy and game quality

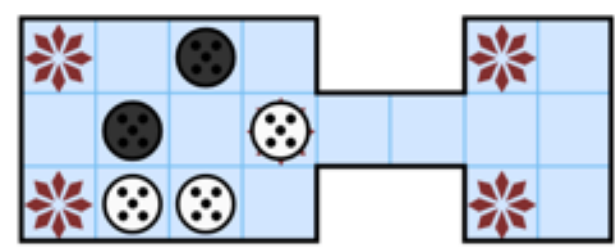


Diagram of a game board with red star symbols and dice pieces. The board is a 3x6 grid with a central 1x2 gap. Red star symbols are in the corners. Dice pieces are placed on the board: a black die with 6 dots, a white die with 6 dots, and a white die with 1 dot.

Player 1 (white triangle) has 4 pieces (x4). Player 2 (black triangle) has 5 pieces (x5).

Status	Moves	Analysis	Ludeme	Info
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				

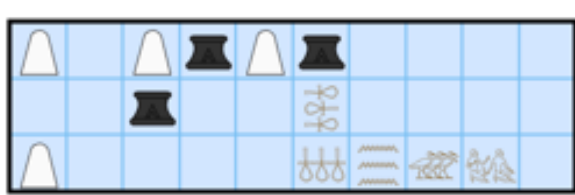


Diagram of a game board with white and black pieces. The board is a 3x6 grid. White pieces are in the top row, and black pieces are in the bottom row. The middle row is empty.

Player 1 (white triangle) has 2 pieces (x2). Player 2 (black triangle) has 2 pieces (x2).

Status	Moves	Analysis	Ludeme	Info
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				
Player 2 to move.				
Player 1 to move.				

Reconstructions of Royal Game of Ur and *senet* in Ludii

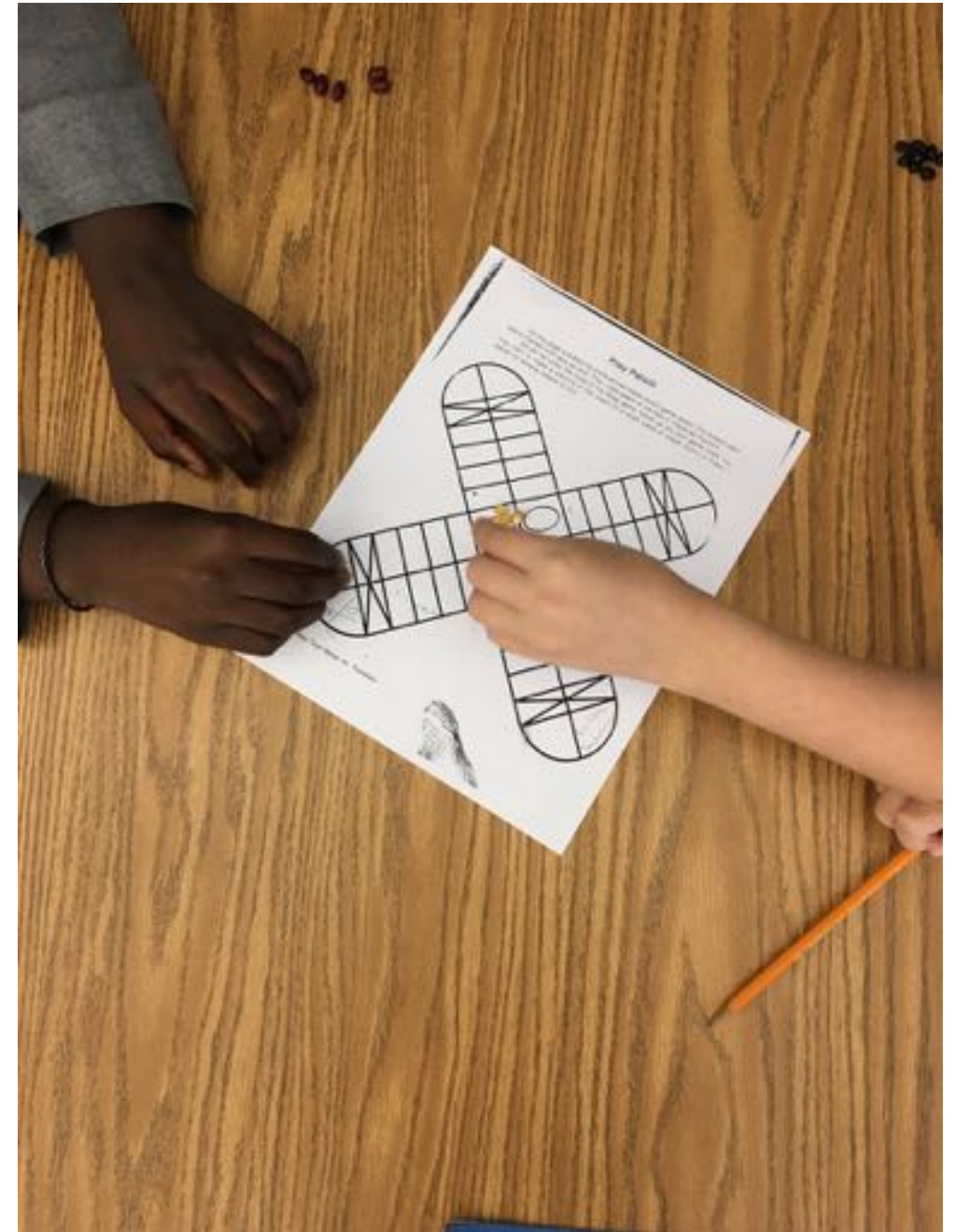
Future Work: Mapping with GeaChron

- Geographic database of cultures and trade routes through time
- Can be used to track possible lines of transmission (through trade or conquest) between regions
- Only covers historical data; archaeological and anthropological data are absent



Preserving Cultural Heritage

- Many of these games are being played less, in favor of commercially sold games
- Some are likely already gone
- Resurrection of ancient and historical games can help people to engage with the past in new ways



Thank You!

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Follow us!

- Twitter: @archaeoludology; @LudiiGames
- Facebook: Digital Ludeme Project

Download Ludii and start playing at ludii.games/download.php

More info: www.ludeme.eu

Contact us: walter.crist@maastrichtuniversity.nl; ludii.games@gmail.com

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