

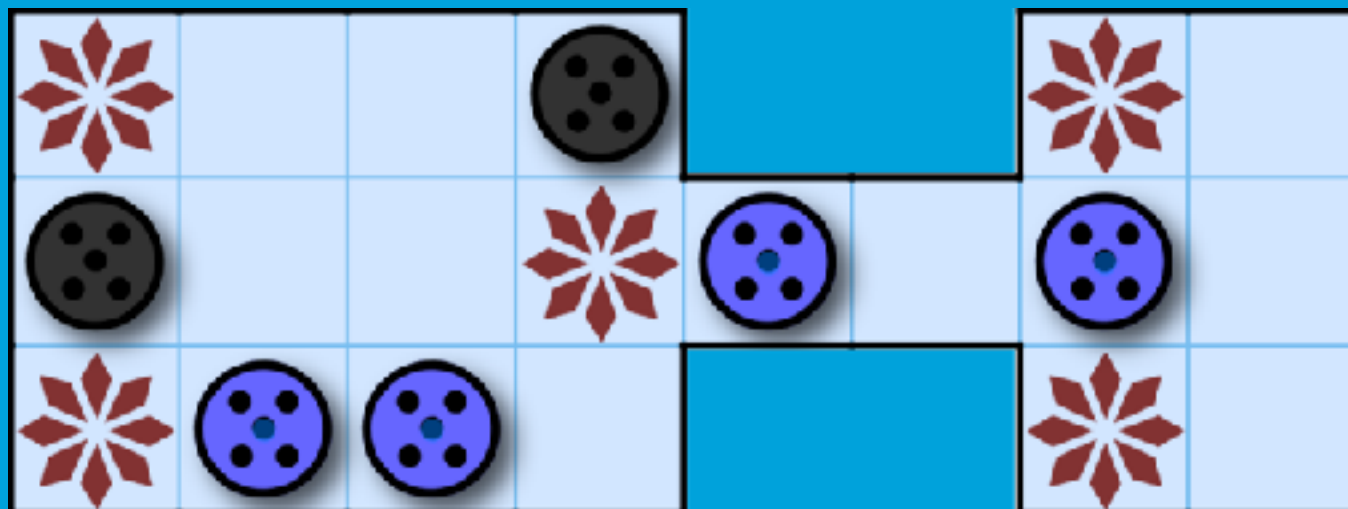
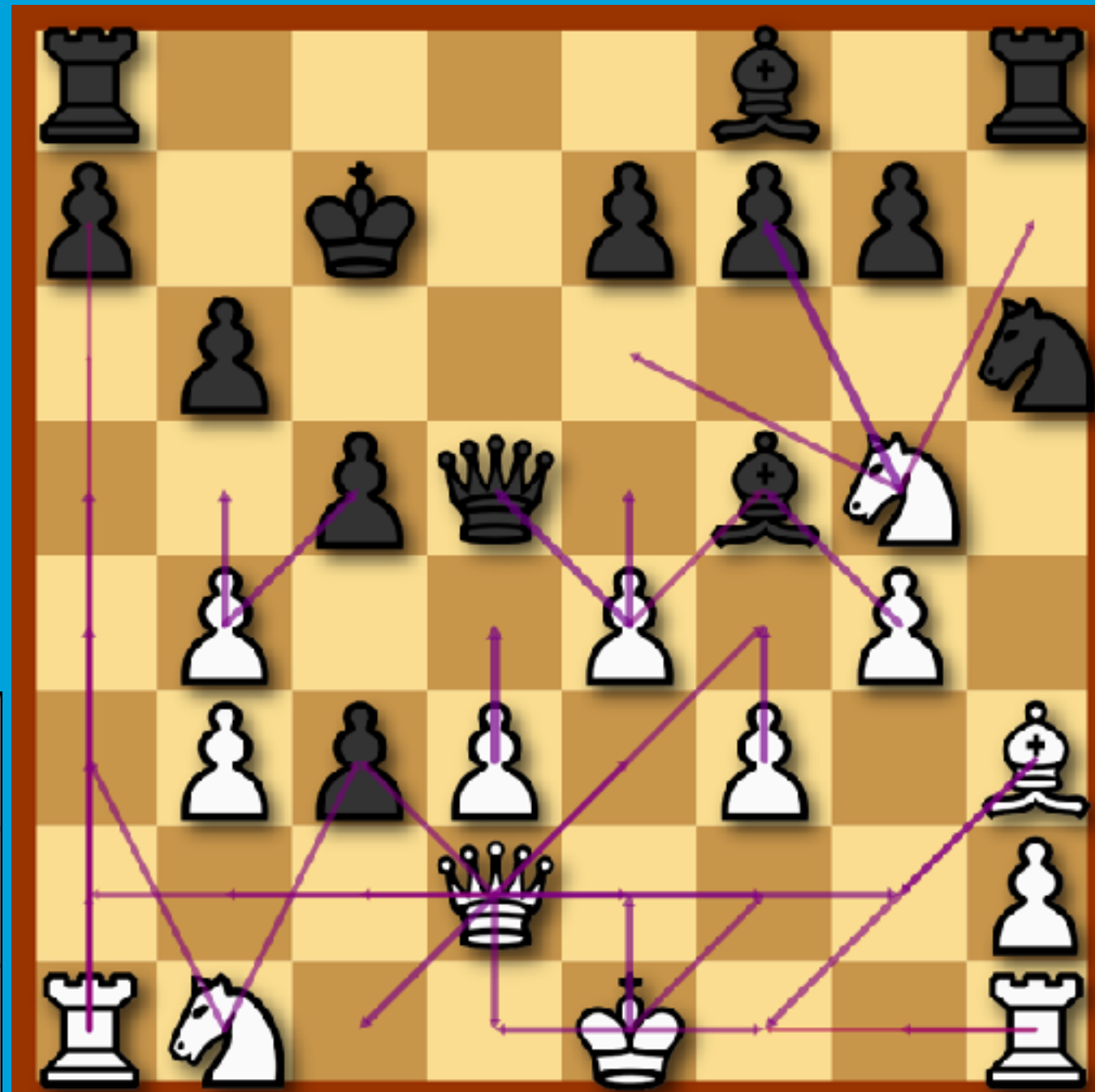
BGS 2019

Teaching and Learning with Ludii

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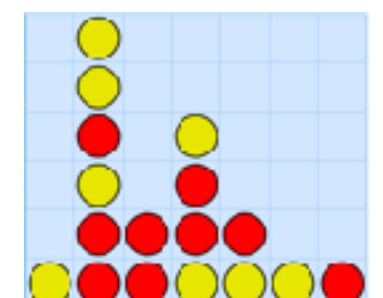
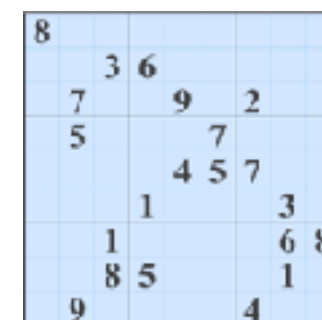
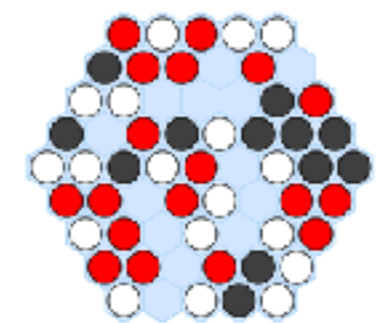
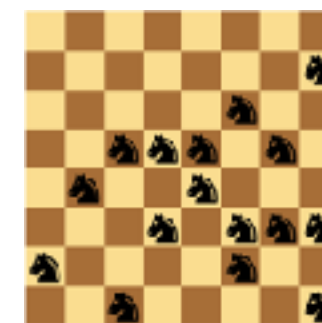
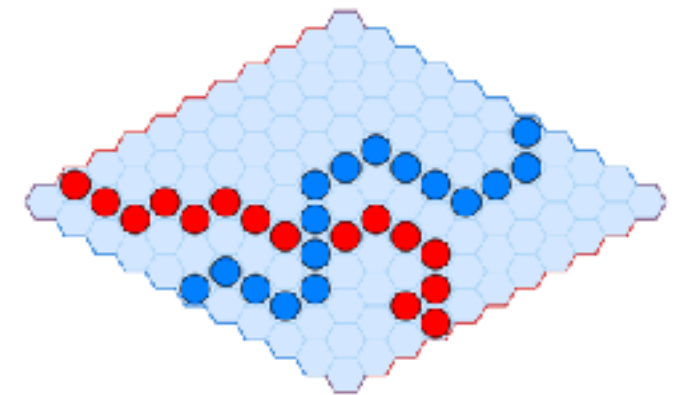
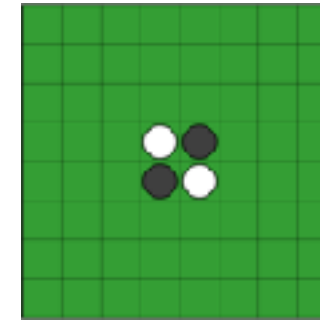
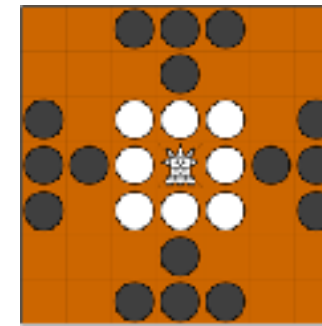
LUDII

LUDII general game system for:

- Modelling
- Playing
- Evaluating
- Optimising
- Generating

Describe a large assortment of strategy games across many different cultures and time periods.

Games described in a simple and clear manner, with easily adjustable properties.



Ludemes

- Game “memes”:
 - Units of game-related information
 - Building blocks (DNA) of games
- Encapsulate key concepts

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e.g.

(tiling square)

(size 3 3)

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e.g.

```
(tiling square)
```

```
(size 3 3)
```

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

Ludemes

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 - Units of game-related information
 - Building blocks (DNA) of games
- Encapsulate key concepts

e.g.

```
(tiling square)
```

```
(size 3 3)
```

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

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

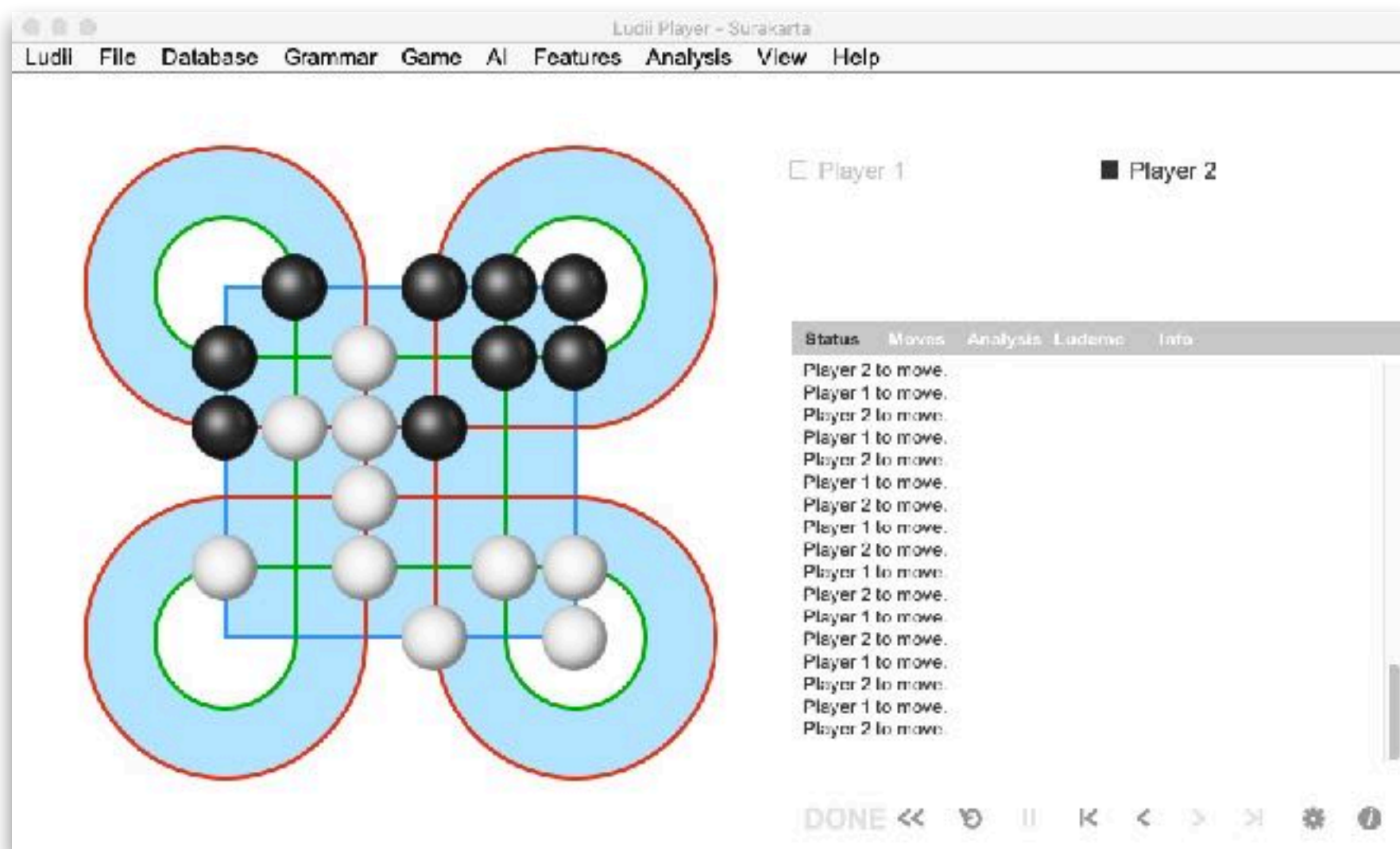
Benefits

- **Simple:** Define new games in minutes/seconds
- **Powerful:** Only approach to model full range of games
- **Compact:** Small file sizes (QR codes)
- **Comprehensible:** Human-readable
- **Efficient:** Our ludemic Chess is 10,000x faster than GGP
- **Convenient:** Easy to manipulate and evolve
- **Granular:** Break games down, label with math. keywords



Visual Style

- Clean, abstract, informative, but attractive
- Emphasis on usability and ease of analysis



First Public Release of LUDII on August

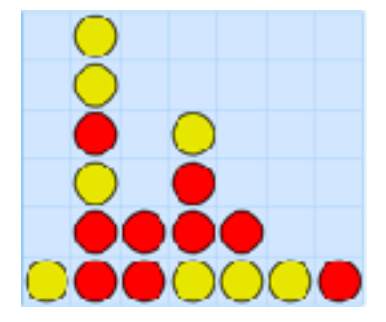
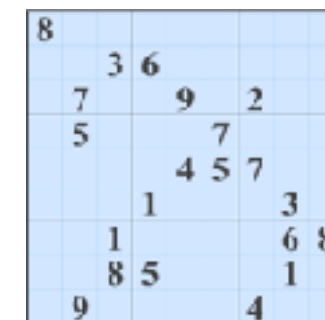
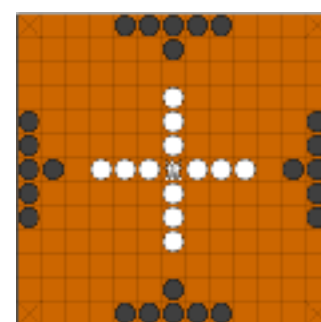
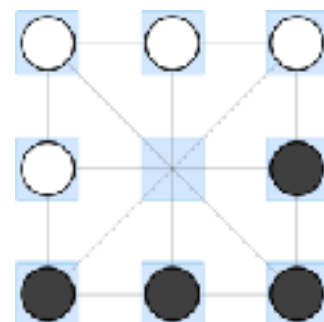
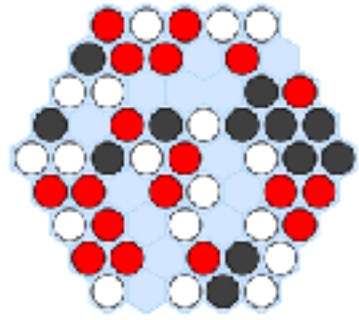
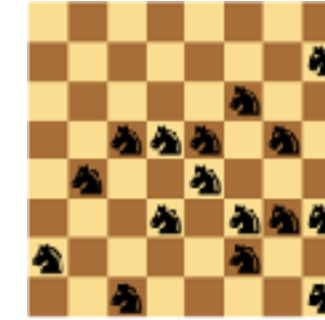
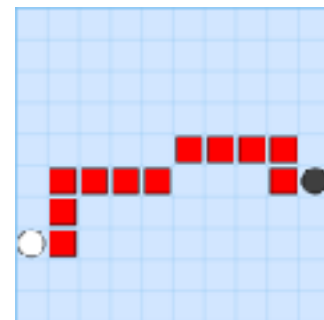
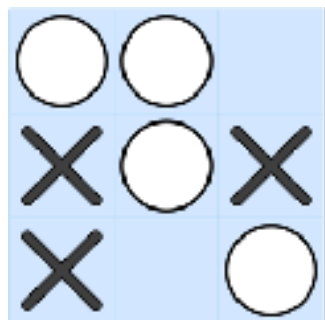
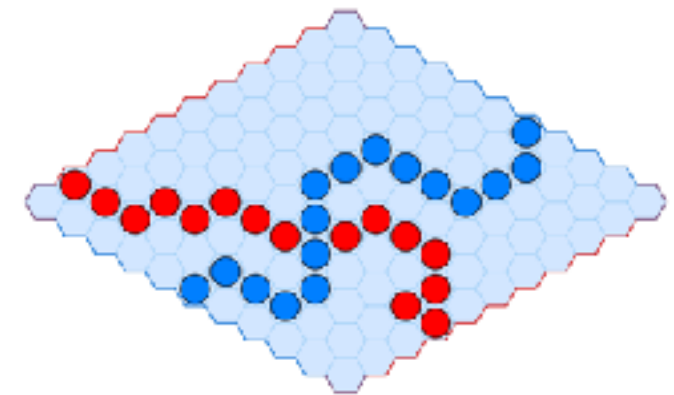
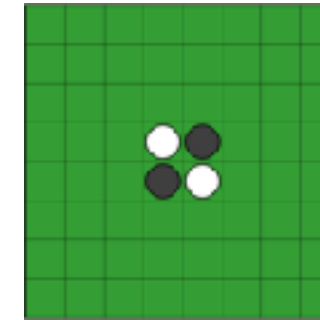
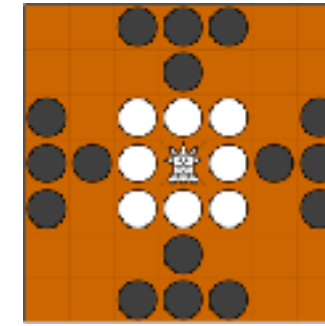
<http://www.ludii.games>

Teaching and Learning

Educate students about:

- Game design principles
- AI techniques
- Mathematical concepts
- History and culture of board games

Interactive tool in lectures or classrooms.

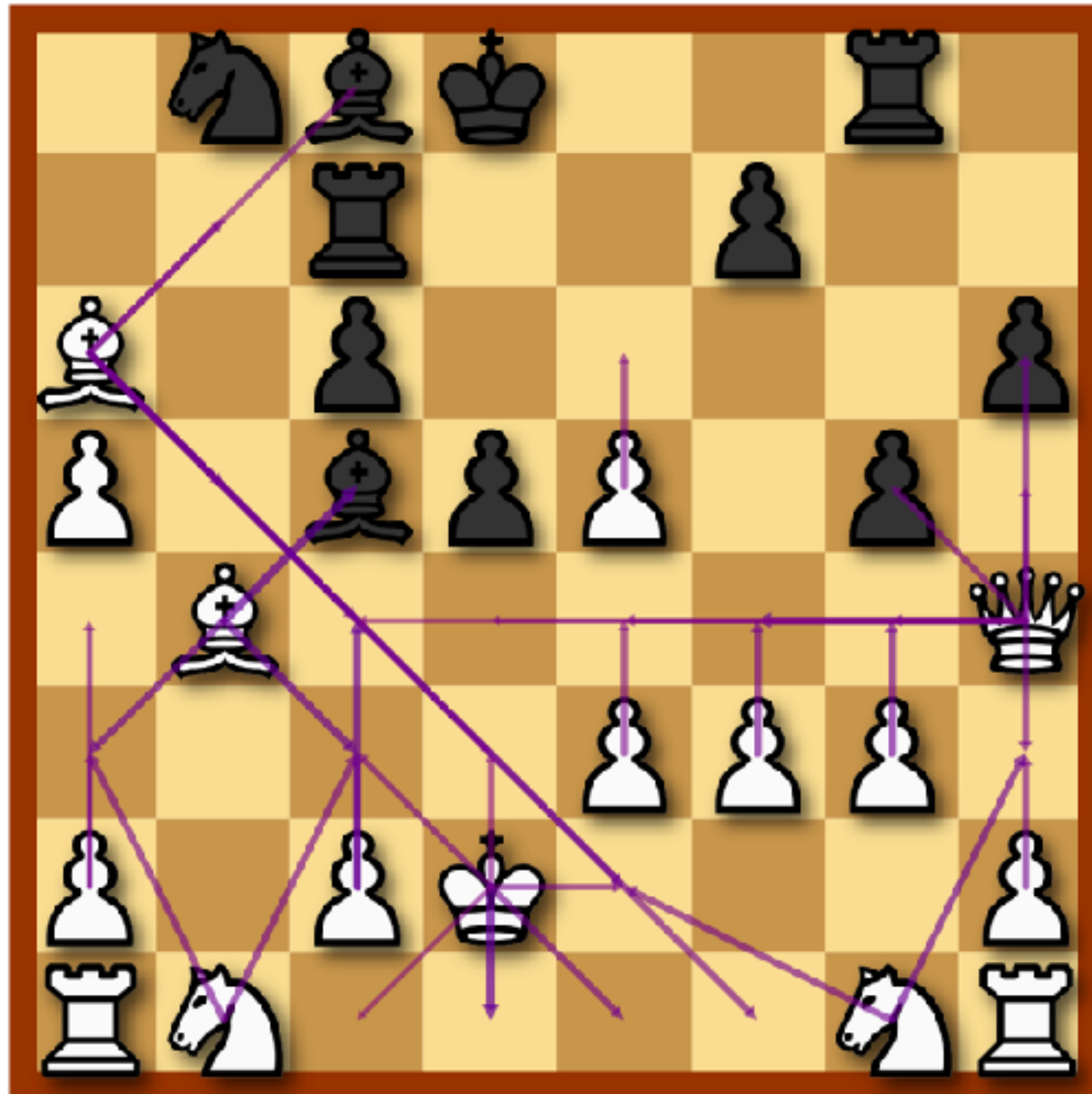


Game Analysis using AI

- AI can often identify flaws and weaknesses in games much easier and faster than humans can.
- Help us to understand good game design principles.
- Evaluate games in terms of different quality metrics:
 - Fairness / Biases
 - Strategic Depth
 - Rules Complexity
 - Game Length
 - Drawishness

Game Analysis using AI

Ludi Player - Chess (Skirmish)
Ludi File Database Games Game Features Analysis View Help



☐ Player 1

Status	Moves	Analysis	Ludeme	Info
UCT made move after 831 iterations (selected child visits = 48, value = 0.0008333333333333332)				
UCT made move after 854 iterations (selected child visits = 40, value = 0.0416666666666666664)				
UCT made move after 758 iterations (selected child visits = 48, value = 0.0416666666666666664)				
UCT made move after 967 iterations (selected child visits = 37, value = 0.05105105105105105106)				
UCT made move after 944 iterations (selected child visits = 39, value = 0.05120205120205120)				
UCT made move after 929 iterations (selected child visits = 33, value = 0.0909090909090909091)				
UCT made move after 945 iterations (selected child visits = 51, value = 0.058623529411764705)				
UCT made move after 949 iterations (selected child visits = 20, value = 0.10714285714285714)				
UCT made move after 964 iterations (selected child visits = 52, value = 0.057692307692307696)				
UCT made move after 953 iterations (selected child visits = 28, value = 0.10714285714285714)				
UCT made move after 997 iterations (selected child visits = 43, value = 0.08787878787878788)				
UCT made move after 972 iterations (selected child visits = 28, value = 0.07142857142857142)				
UCT made move after 1013 iterations (selected child visits = 40, value = 0.075)				
UCT made move after 959 iterations (selected child visits = 31, value = 0.12803225806451613)				
UCT made move after 1011 iterations (selected child visits = 35, value = 0.08571428571428572)				
UCT made move after 1008 iterations (selected child visits = 34, value = 0.050020529411764705)				
UCT made move after 1070 iterations (selected child visits = 49, value = 0.08163265305122448)				
UCT made move after 1070 iterations (selected child visits = 35, value = 0.08571428571428572)				
UCT made move after 979 iterations (selected child visits = 47, value = 0.0051063829737234)				
UCT made move after 1043 iterations (selected child visits = 34, value = 0.11764705882352941)				
UCT made move after 1080 iterations (selected child visits = 46, value = 0.081224489795918366)				
UCT made move after 1022 iterations (selected child visits = 35, value = 0.11428571428571428)				
UCT made move after 1058 iterations (selected child visits = 48, value = 0.043478260869565216)				
UCT made move after 1047 iterations (selected child visits = 34, value = 0.11764705882352941)				
UCT made move after 1092 iterations (selected child visits = 67, value = 0.05970149253731345)				
UCT made move after 1091 iterations (selected child visits = 40, value = 0.175)				
UCT made move after 1108 iterations (selected child visits = 40, value = 0.0416666666666666664)				
UCT made move after 1071 iterations (selected child visits = 38, value = 0.20512820512820512)				
UCT made move after 1098 iterations (selected child visits = 60, value = 0.02)				
UCT made move after 1078 iterations (selected child visits = 33, value = 0.15151515151515152)				
UCT made move after 1055 iterations (selected child visits = 45, value = 0.022222222222222223)				
UCT made move after 1075 iterations (selected child visits = 40, value = 0.2)				
UCT made move after 1142 iterations (selected child visits = 48, value = 0.0)				
UCT made move after 1180 iterations (selected child visits = 49, value = 0.2853061224489796)				
UCT made move after 1151 iterations (selected child visits = 51, value = 0.0)				
UCT made move after 1155 iterations (selected child visits = 42, value = 0.23609523809523808)				
UCT made move after 1140 iterations (selected child visits = 53, value = 0.018867924528301886)				
UCT made move after 1138 iterations (selected child visits = 36, value = 0.21052631578947367)				
UCT made move after 1174 iterations (selected child visits = 51, value = 0.0186078431372549)				

Transcription Errors

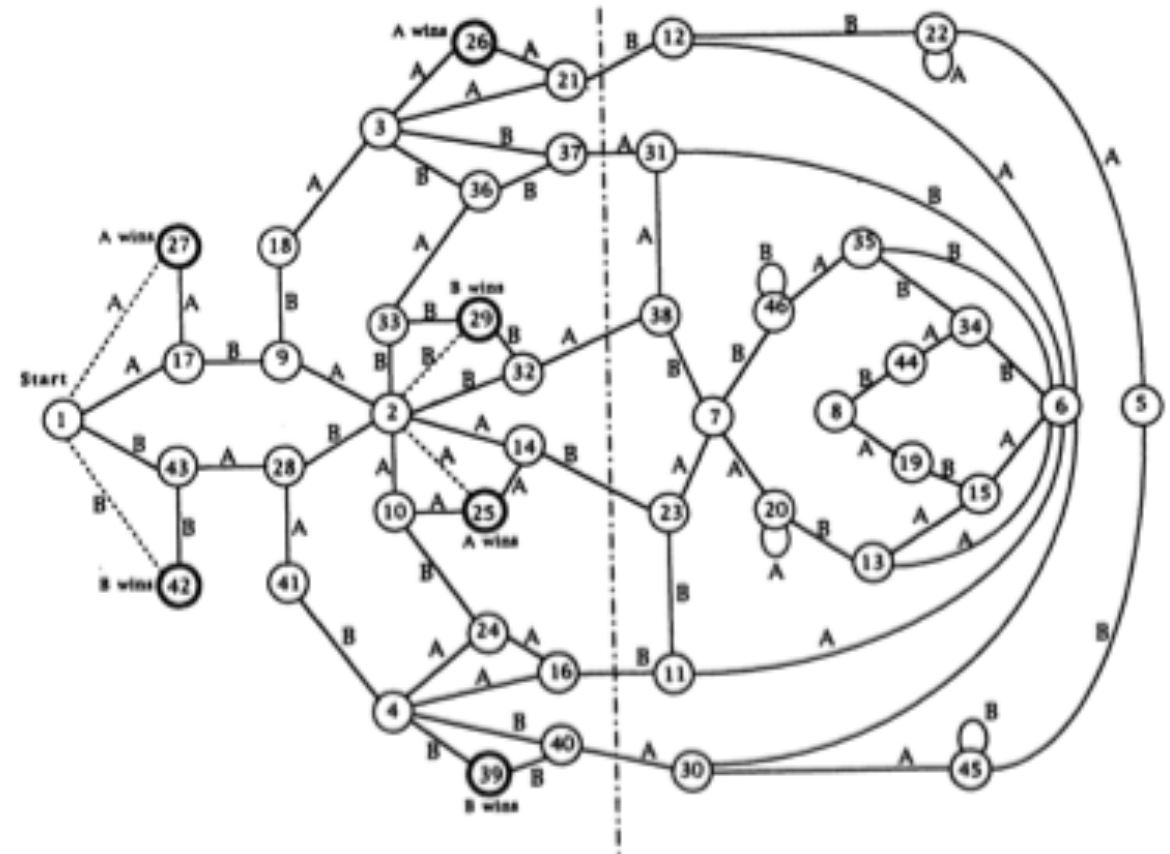
Mu Torere

- Maori, New Zealand, 18thC
- Key rule: *Can only move to centre if adjacent to enemy piece*



Ascher (1987) survey

- Two historical accounts omit this rule
- Game ends after 1 move
- Not how it is played
- Simplest analysis would have revealed this



Translation Errors

Hnefatafl

- Scandiavia, c.400BC
- No rules found

Linnaeus (1732)

- Saw Tablut played
- Recorded in travel diary (in Latin)

Smith (1811)

- Translated into English

Murray (1913) *History of Chess*

- Published rules, became de facto



Translation Errors

BUT...

Smith's translation
had a critical error:

- “...likewise the king...”
not
- “...except the king...”

King almost impossible to capture:

- King's side always wins
- Biased game, corrected ever since
- **Not how it was played**

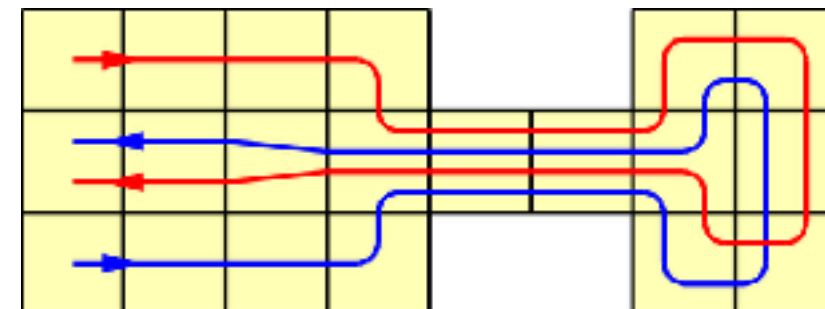
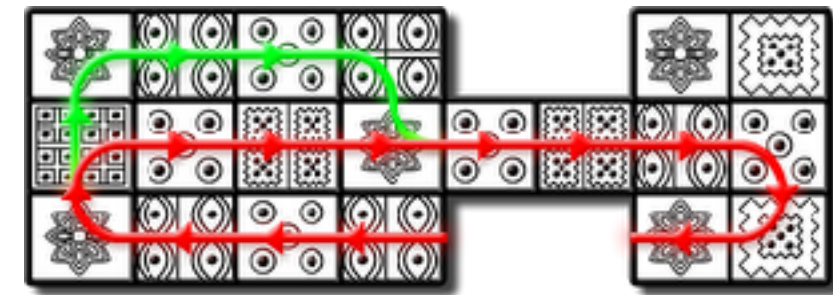
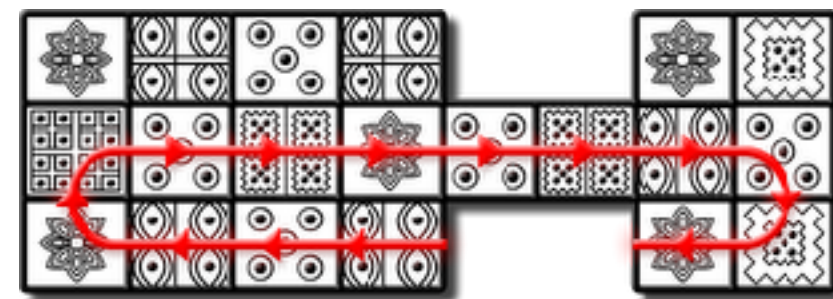


Royal Game of UR

- Mesopotamia, 2600_{BC}

Oldest recorded rules:

- Found by Finkel (1990)
- Lucky find!
- Losing game evidence all the time
- Royal Game of Ur:
 - Which track?



Example exercise for teaching

Poprad Game (Slovakia)

- Tomb dated to 375AD
- Germanic chieftain

Board:

- 17x15/16 grid

Pieces:

- 2 x Colours
- 1 or 2 x Sizes?



Task students to identify a strategically deep and balanced set of game rules that involve these components.

Visualising AI techniques

- Many different algorithms and AI techniques exist for playing games.
- Monte Carlo Tree Search (MCTS)
- Upper Confidence Bound (UCT)
$$A_t = \begin{cases} \operatorname{argmax}_i \left(\hat{\mu}_i(t-1) + \sqrt{\frac{2 \log f(t)}{T_i(t-1)}} \right), & \text{if } t > K; \\ t, & \text{otherwise.} \end{cases}$$
- Rolling Horizon Evolution
$$a^* = \operatorname{argmax}_{a \in A(s)} \left\{ Q(s, a) + C \sqrt{\frac{\ln N(s)}{N(s, a)}} \right\}$$
- StockFish (Chess)
- AlphaZero (Go, Shogi, many others)
- Difficult to visualise how exactly these algorithms think.

Visualising AI techniques

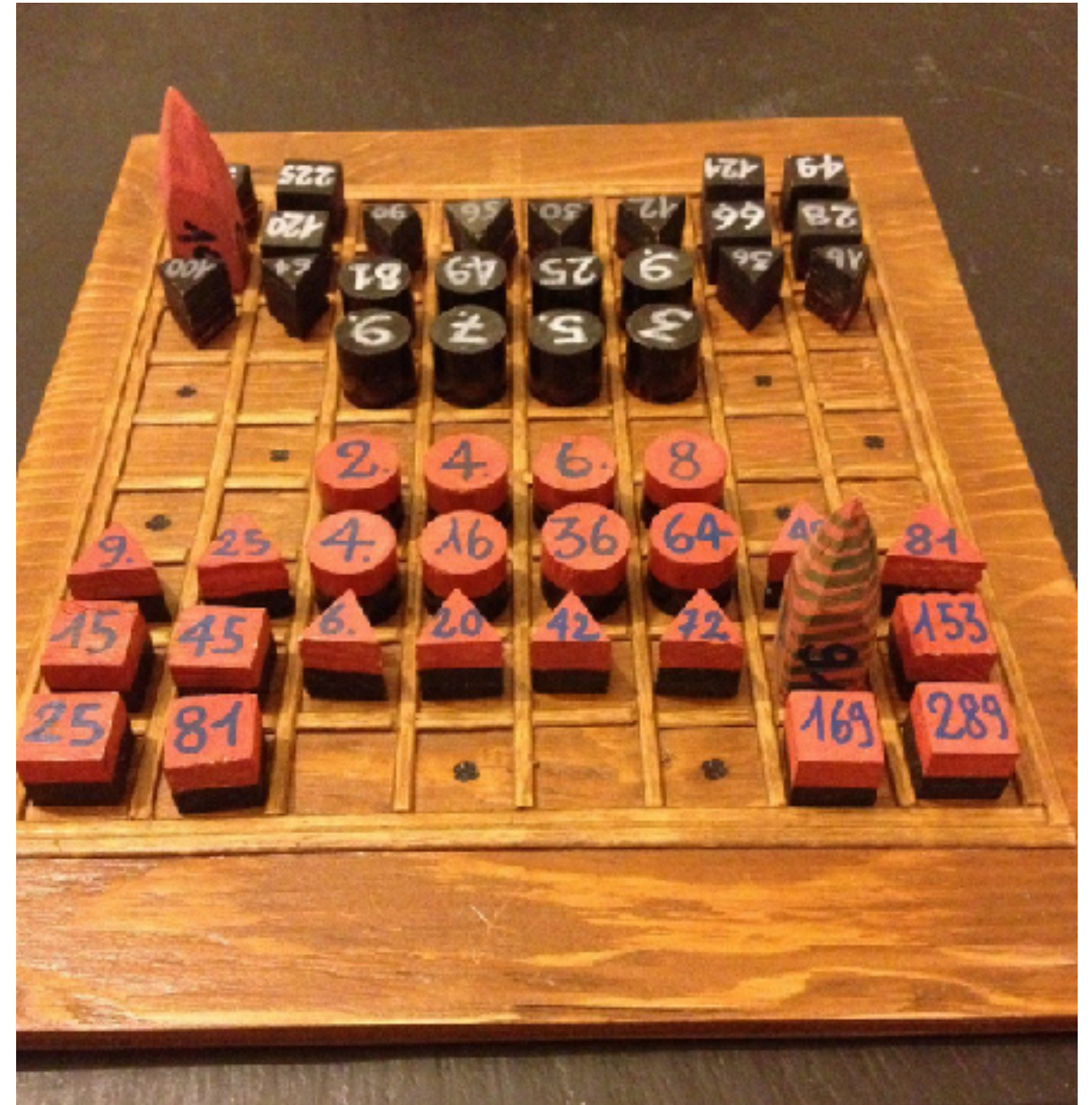
- Ludii allows us to visualise how these algorithms perform for any game.
 - How much an AI is thinking about a move.
 - How good or bad the AI thinks a move is.
 - How confident the AI is that it can win.
- Identify limitations in our AI techniques.
- AI can help identify new game strategies not previously considered by humans.
- Demo!

Games and Mathematics

Tagging ludemes with underlying mathematical concepts:

- Geometry
- Logic
- Algebra
- Arithmetic
- Etc.

Identify which games can help teachers to demonstrate different mathematical ideas to students.



Rithmomachia (11thC)

History and Culture

- Games are an important part of many cultures and have a long history.
- Another aspect of Ludii will involve recording historical and cultural evidence for each game.
- Can provide many tools for teaching the history of games.



GeoCron

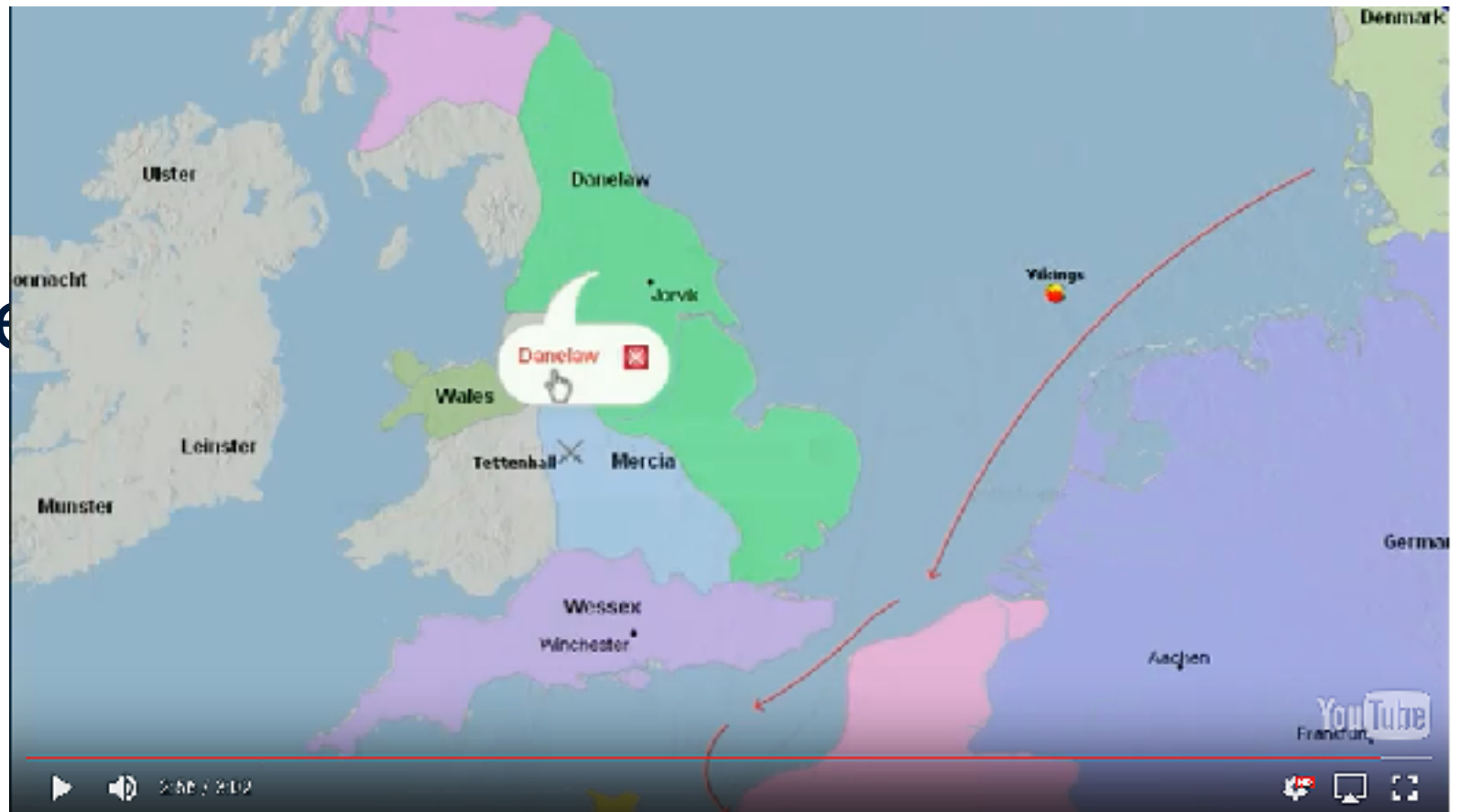
Geo-temporal database

Yearly maps:

- 3,000BC—today
- 2,000 civilisations

Provide GPS+date:

- Culture/civilisation
- Country/nation/state
- Political boundaries
- Historical sites/events
- Trade/exploration routes

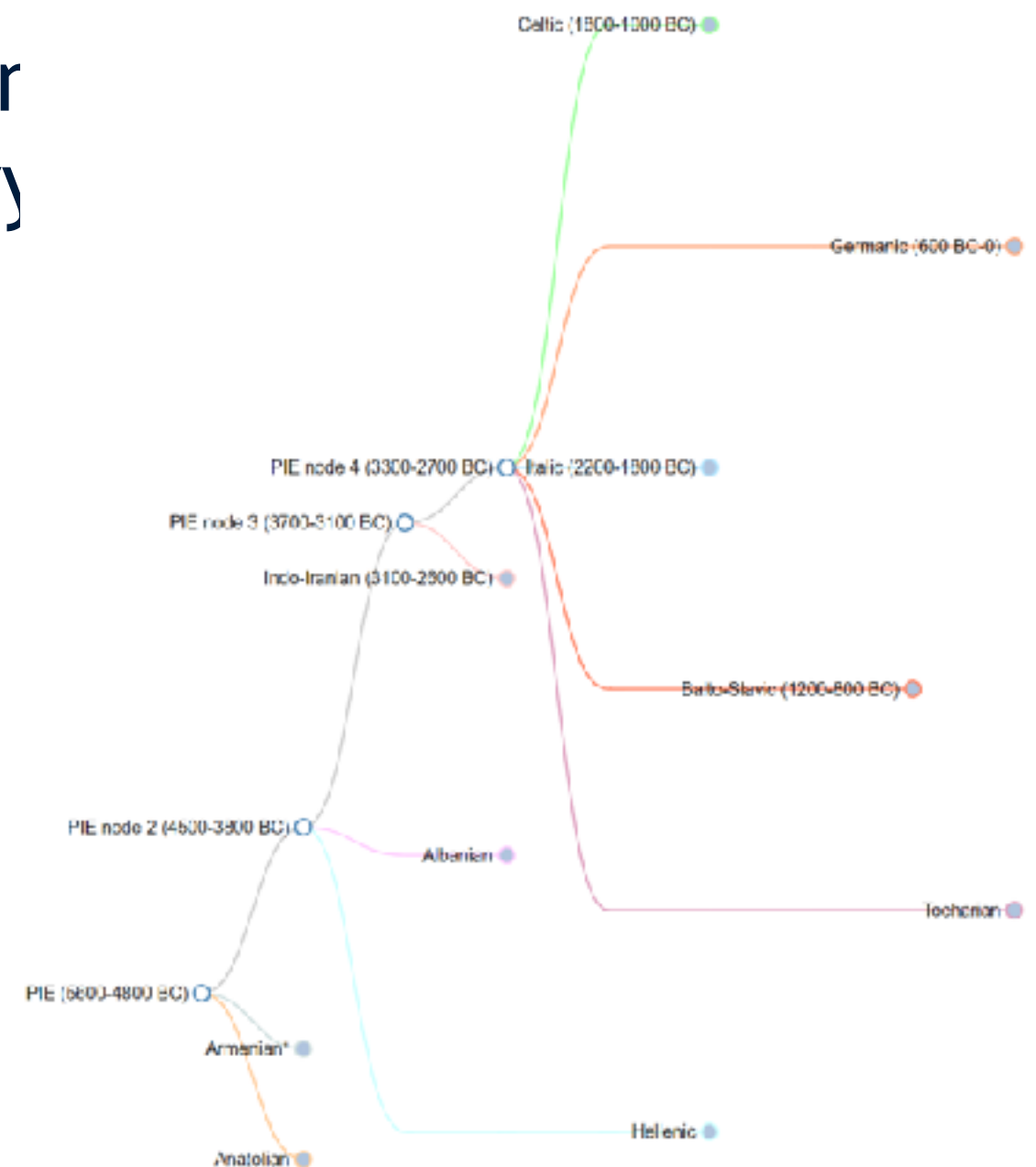
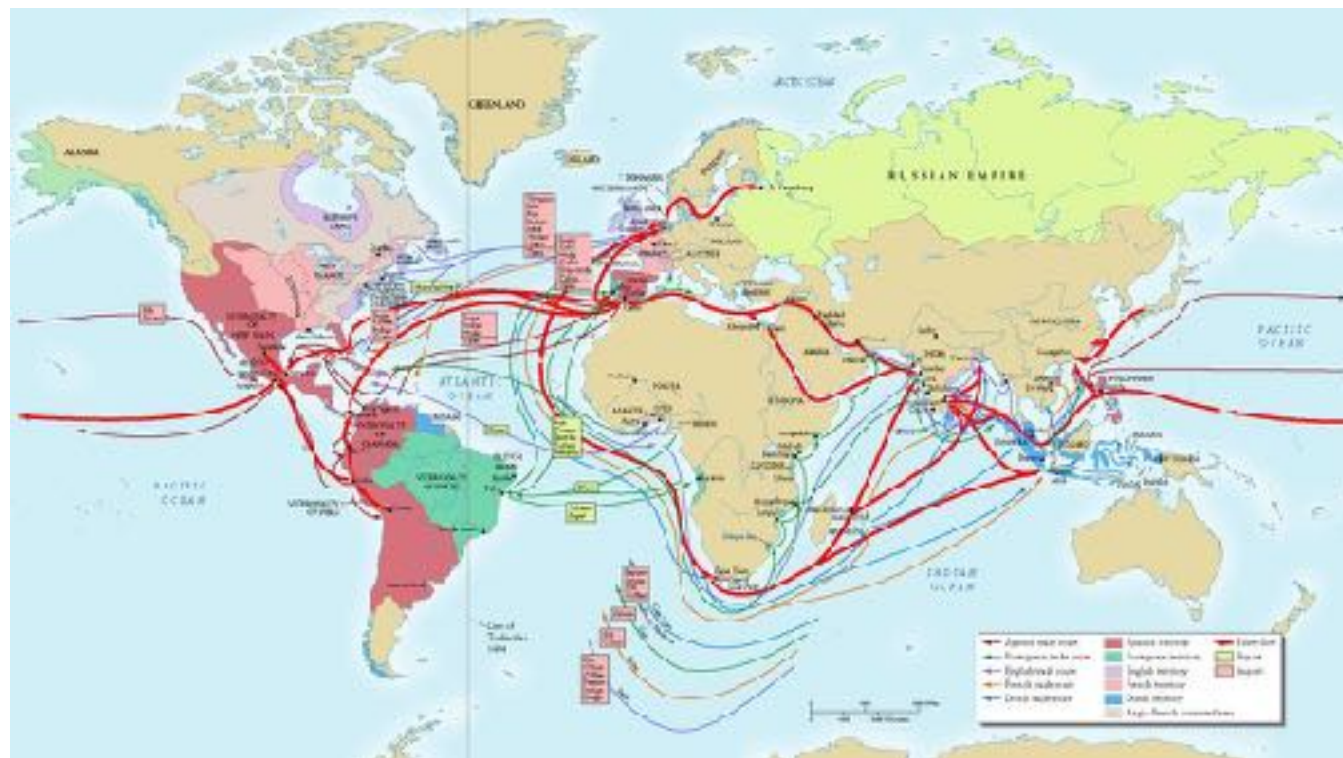


GeoCron: Viking route from Norway to Paris (845AD)



Visualising the History and Spread of Games

- Use an interactive map to represent the spread of games and ludemes across time and place.
- Possible to trace individual games or ludemes throughout history (family tree or network).



Conclusion



<http://www.ludeme.eu>

Thank You!

First Release of LUDII on August

<http://www.ludii.games>



Go
China, 548BC
(Japanese players)

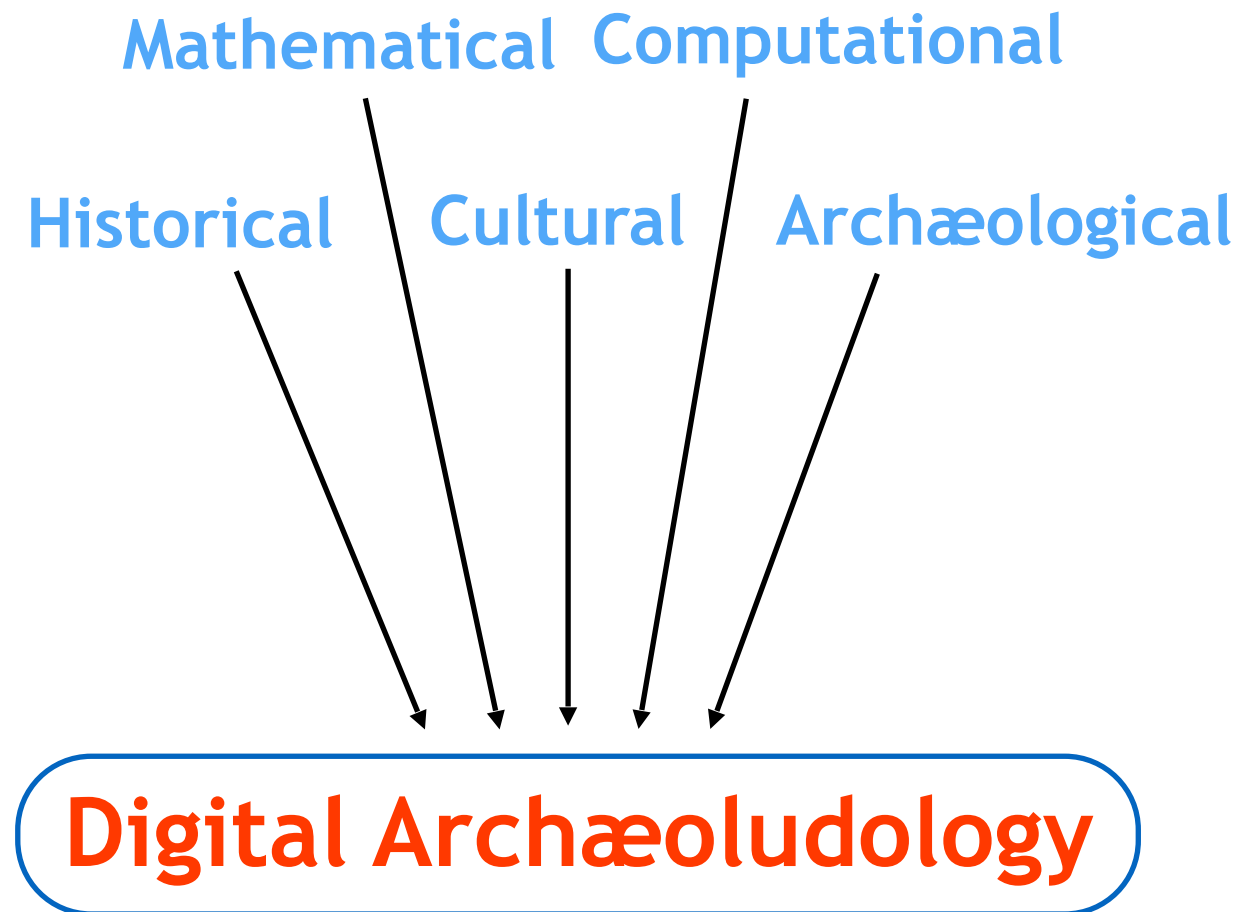
Digital Archæoludology

Digital Archæoludology:

- New field of research
- Several research strands
- Single unified approach

Modern comput. techniques:

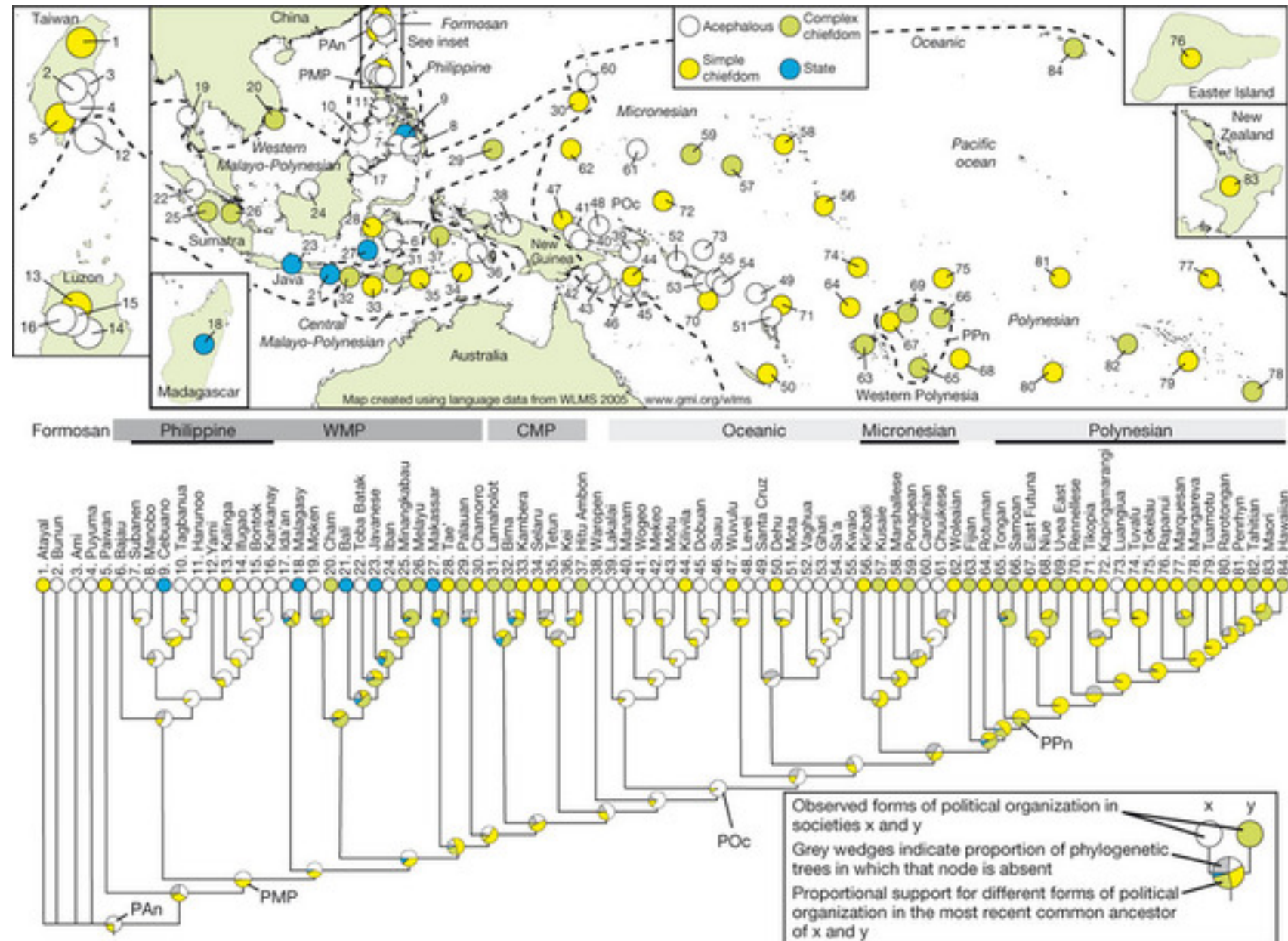
- Analysis and reconstruction
- Incomplete descriptions



Computational Phylogenetics

“Family tree” of traditional games

- Principles similar to linguistics
- Ancestral state reconstruction
- Missing links?



Phylogenetic analysis of Austronesian societies
Currie (2010) *Nature*