

Game Distance and Cultural Social Network

Matthew Stephenson

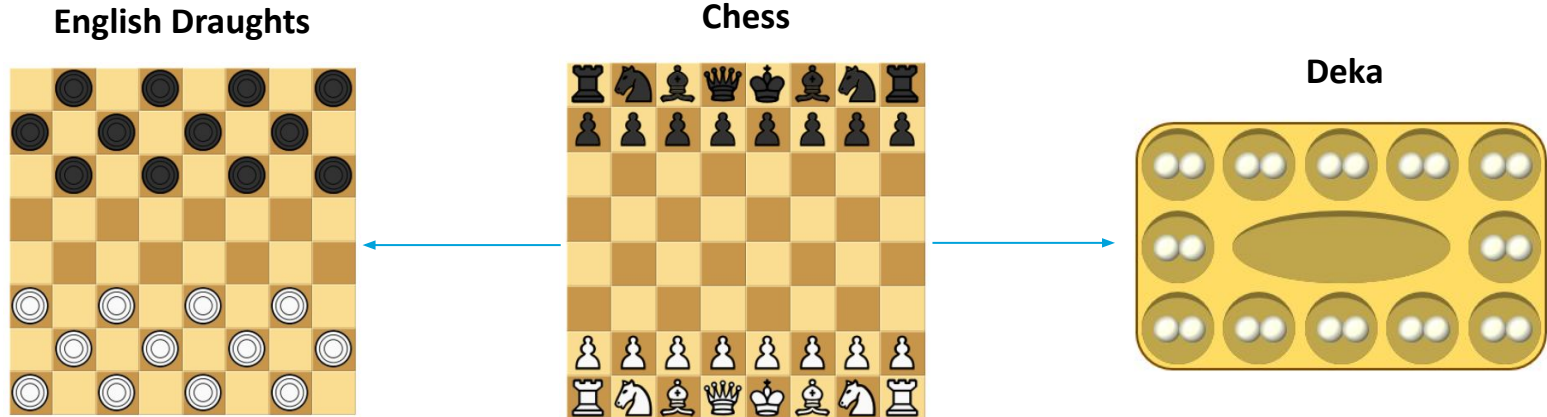
Game AI Applications for Historical Games Research
13 April 2022

Motivation

Define measure of distance between two games.

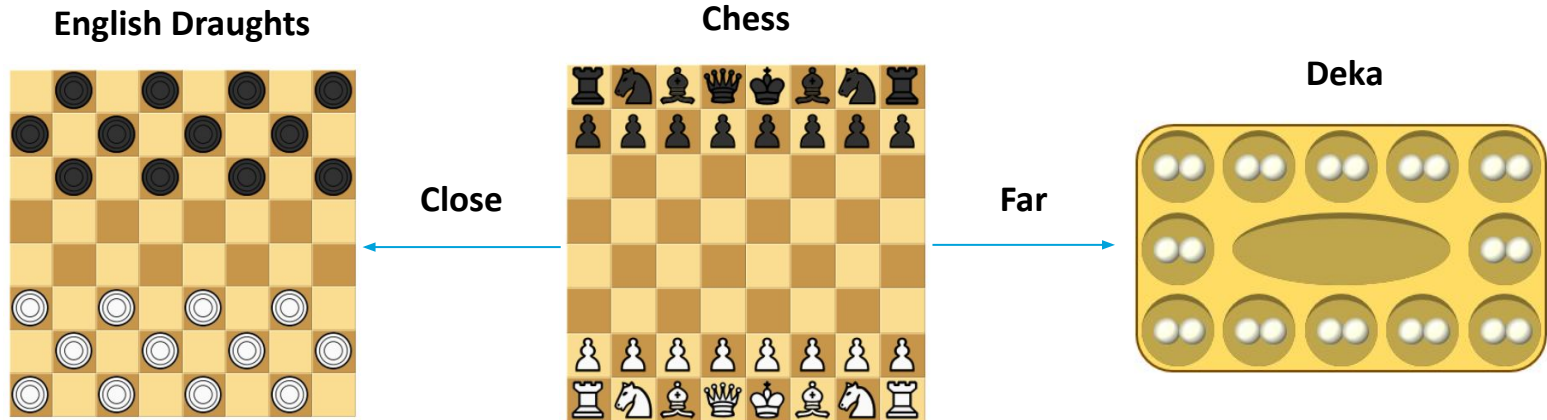
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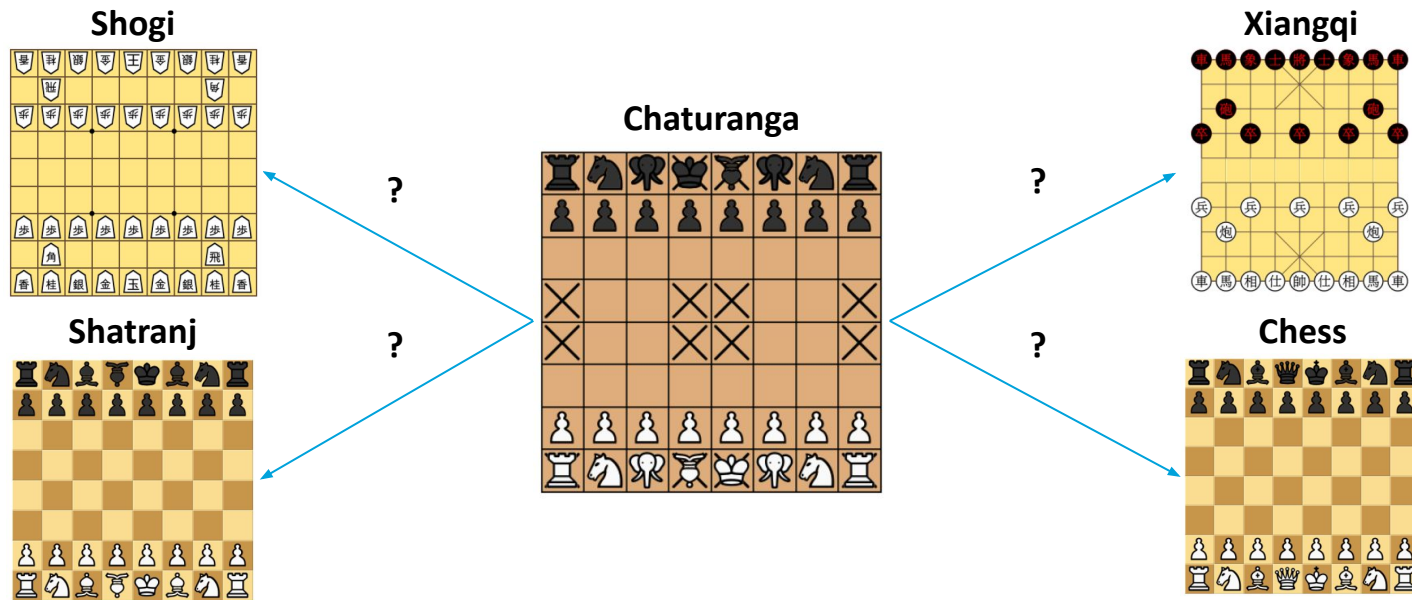
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Game Properties

Game Properties

Gameplay properties:

- Rules, equipment, behaviour

Game Properties

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- Rules, equipment, behaviour

Cultural properties:

- Location, period, context

Game Properties

Gameplay properties:

- Rules, equipment, behaviour

Cultural properties:

- Location, period, context

Use these properties to estimate game distance.

Gameplay Properties

Obtained from the Ludii software.

Gameplay Properties

Obtained from the Ludii software.

- Ludemes

```
(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)))  
  )  
)
```

Gameplay Properties

Obtained from the Ludii software.

- Ludemes
- Concepts

Concepts for Game Tic-Tac-Toe

Standard

Properties

Properties, Format, Time, Discrete, Turns, Alternating, Asymmetric, AsymmetricForces, AsymmetricPiecesType, Players, NumPlayers(2), TwoPlayer

Equipment

Equipment, Container, Board, Shape, SquareShape, NumRows(3), NumCorners(4), NumDirections(4.44), NumOrthogonalDirections(2.67), NumDiagonalDirections(1.78), NumAdjacentDirections(4.44), NumOuterSites(8), NumInnerSites(1), NumLayers(1), Tiling, SquareTiling, NumEdges(24), NumCells(9), NumVertices(16), NumPerimeterSites(8), NumTopSites(3), NumBottomSites(3), NumRightSites(3), NumLeftSites(3), NumCentreSites(1), NumConvexCorners(4), NumPhasesBoard(2), PlayableSites, Cell, NumPlayableSitesOnBoard(9), NumColumns(3), NumContainers(1), NumPlayableSites(9), Component, Piece, NumComponentsType(2), NumComponentsTypePerPlayer(1)

Start

Play

Rules, Play, Moves, MovesDecision, PassDecisionFrequency(3%), SingleSiteMoves, AddDecision, AddDecisionFrequency(97%), Conditions, SpaceConditions, Line, Directions, AbsoluteDirections, AdjacentDirection, NumPlayPhase(1), LineEndFrequency(83%), LineWinFrequency(83%), DrawFrequency(17%)

End

End, SpaceEnd, LineEnd, LineWin



Gameplay Properties

Obtained from the Ludii software.

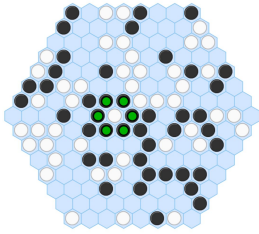
- Ludemes
- Concepts
- Metrics

Agent type:	Random
Draw likelihood:	30%
Player 1 win rate:	75%
Player 2 win rate:	25%
Balance:	0.5
Completion:	0.7
Drawishness:	0.3
Board Coverage Default:	0.9

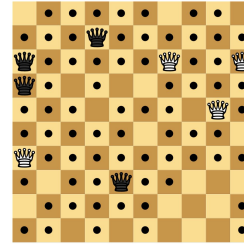
Gameplay Distance

Calculate distance between two games based on how different their gameplay properties are.

Ludeme Distance

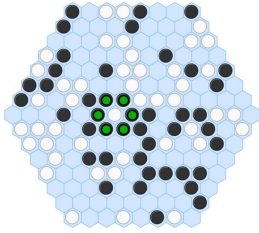


```
(game "Havannah"
  (players 2)
  (equipment {
    (board (hex 8))
    (piece "Marker" Each)
  })
  (rules
    (play (move Add (to (sites Empty))))
    (end
      (if
        (or {
          (is Loop)
          (is Connected 3 SidesNoCorners)
          (is Connected 2 Corners)
        })
        (result Mover Win)
      )
    )
  )
)
```

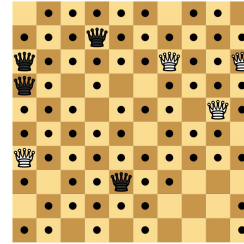


```
(game "Amazons"
  (players 2)
  (equipment {
    (board (square 10))
    (piece "Queen" Each (move Slide (then (moveAgain))))
    (piece "Dot" Neutral)
  })
  (rules
    (start {
      (place "Queen1" {"A4" "D1" "G1" "J4"})
      (place "Queen2" {"A7" "D10" "G10" "J7"})
    })
    (play
      (if (is Even (count Moves))
        (forEach Piece)
        (move Shoot (piece "Dot0"))
      )
    )
    (end (if (no Moves Next) (result Mover Win)))
  )
)
```

Ludeme Distance

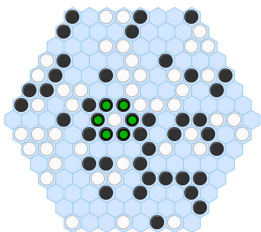


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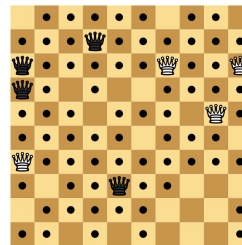
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```

Ludeme Distance



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      )
    )
  )
)
```

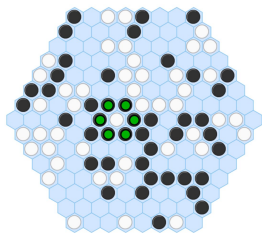
Shared = 17



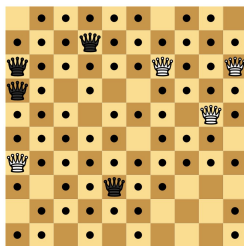
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(game "Amazons"
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  (equipment {
    (board (square 10))
    (piece "Queen" Each (move Slide (then (moveAgain))))
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      (if (is Even (count Moves))
        (forEach Piece)
        (move Shoot (piece "Dot0"))
      )
    )
    (end (if (no Moves Next) (result Mover Win)))
  )
)
```

Different = 28

Concept/Metric Distance

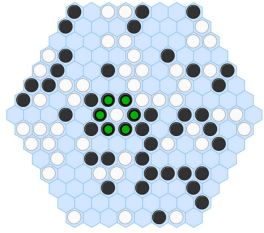


NumRows(15)
NumCorners(6)
NumDirections(10.44)
NumOrthogonalDirections(5.47)
NumDiagonalDirections(4.97)
NumAdjacentDirections(5.47)
NumOuterSites(42)
NumInnerSites(127)
PieceNumberMedian(59.83)
PieceNumberMaximum(119.18)
PieceNumberVariance(1237.94)
UCTWinRate(0.67)

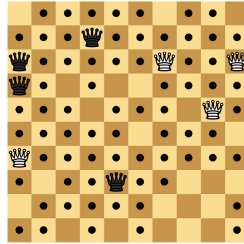


NumRows(10)
NumCorners(4)
NumDirections(6.84)
NumOrthogonalDirections(3.6)
NumDiagonalDirections(3.24)
NumAdjacentDirections(6.84)
NumOuterSites(36)
NumInnerSites(64)
PieceNumberMedian(41.47)
PieceNumberMaximum(75.28)
PieceNumberVariance(387.56)
UCTWinRate(0.81)

Concept/Metric Distance



NumRows(15)
NumCorners(6)
NumDirections(10.44)
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NumRows(10)
NumCorners(4)
NumDirections(6.84)
NumOrthogonalDirections(3.6)
NumDiagonalDirections(3.24)
NumAdjacentDirections(6.84)
NumOuterSites(36)
NumInnerSites(64)
PieceNumberMedian(41.47)
PieceNumberMaximum(75.28)
PieceNumberVariance(387.56)
UCTWinRate(0.81)

Difference

NumRows(5)
NumCorners(2)
NumDirections(3.6)
NumOrthogonalDirections(1.87)
NumDiagonalDirections(1.73)
NumAdjacentDirections(1.37)
NumOuterSites(6)
NumInnerSites(63)
PieceNumberMedian(18.36)
PieceNumberMaximum(43.9)
PieceNumberVariance(850.38)
UCTWinRate(0.14)

Gameplay Distance

Sum Ludeme, Concept and Metric differences between two games.



Gameplay Distance

Sum Ludeme, Concept and Metric differences between two games.

Gives total measure of gameplay distance.

Gameplay Distance

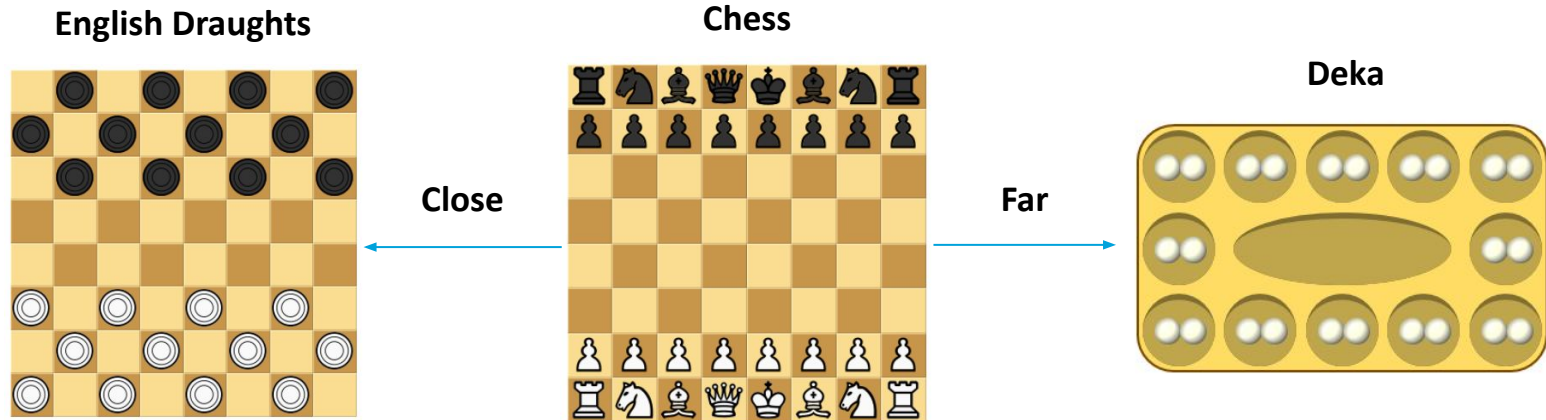
Sum Ludeme, Concept and Metric differences between two games.

Gives total measure of gameplay distance.

Distance values are normalised within 0 - 1 range.

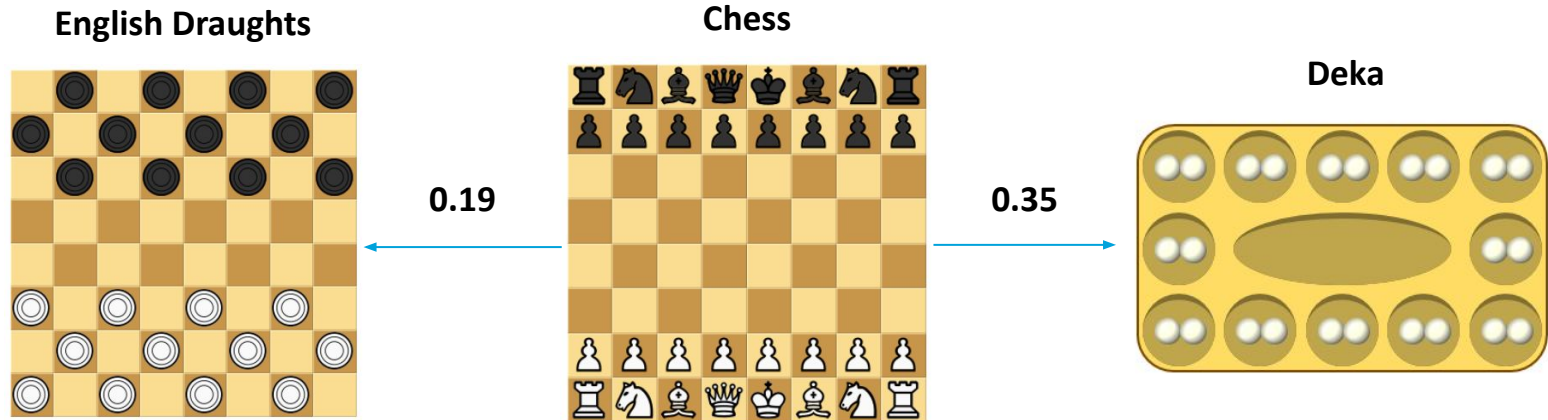
Gameplay Distance Example #1

Define measure of distance between two games.



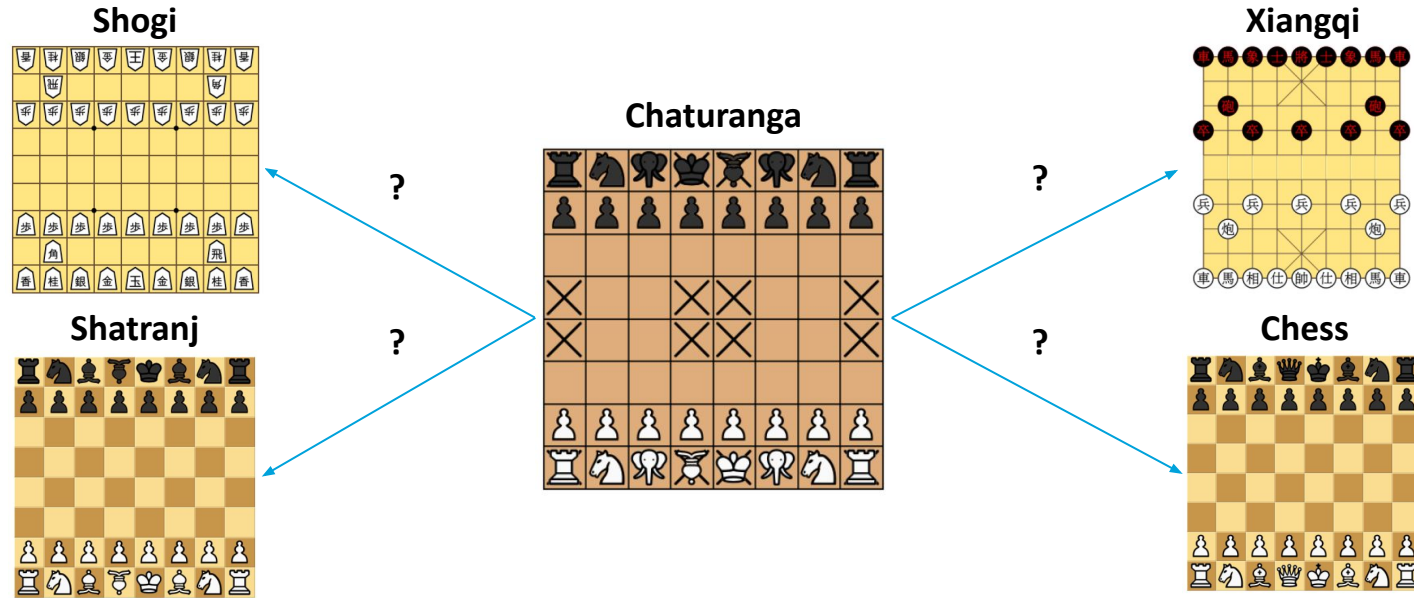
Gameplay Distance Example #1

Define measure of distance between two games.



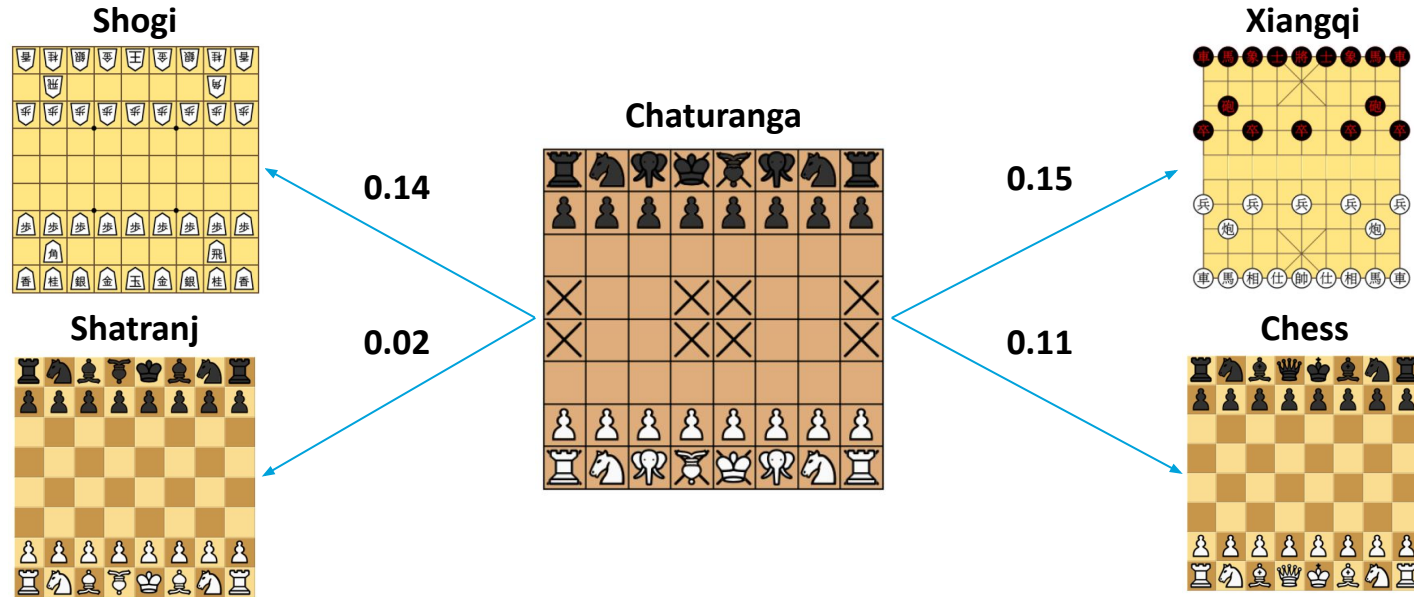
Gameplay Distance Example #2

Define measure of distance between two games.



Gameplay Distance Example #2

Define measure of distance between two games.



Gameplay Distance Applications

Can be used to identify other games with similar mechanisms or playstyles.

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- Select AI for unknown games based on their prior performance.

Gameplay Distance Applications

Can be used to identify other games with similar mechanisms or playstyles.

- Select AI for unknown games based on their prior performance.
- Recommend new games to users based on their personal preferences.

Cultural Properties

Obtained from collected evidence.

Primarily focussing on geo-temporal data.

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Obtained from collected evidence.

Primarily focussing on geo-temporal data.

Coordinate Location(s):

- 30°1'55.75"N, 31°4'31.13"E

Cultural Properties

Obtained from collected evidence.

Primarily focussing on geo-temporal data.

Coordinate Location(s):

- 30°1'55.75"N, 31°4'31.13"E

Date range:

- 1200_{CE} - 1500_{CE}

Cultural Properties

Every DLP game in our database has one or more pieces of associated evidence.

Cultural Properties

Every DLP game in our database has one or more pieces of associated evidence.

The geo-temporal data for game is the combined data from all its evidence.

Senet
346 pieces of evidence
2970_{BCE} - 301_{BCE}



How to Measure Cultural Distance?



Shatranj
15 pieces of evidence
531_{CE} - 1257_{CE}

?



Senet
346 pieces of evidence
2970_{BCE} - 301_{BCE}

Cultural Social Network

Worked with the organisation Geacron to create a cultural social network (CSN).



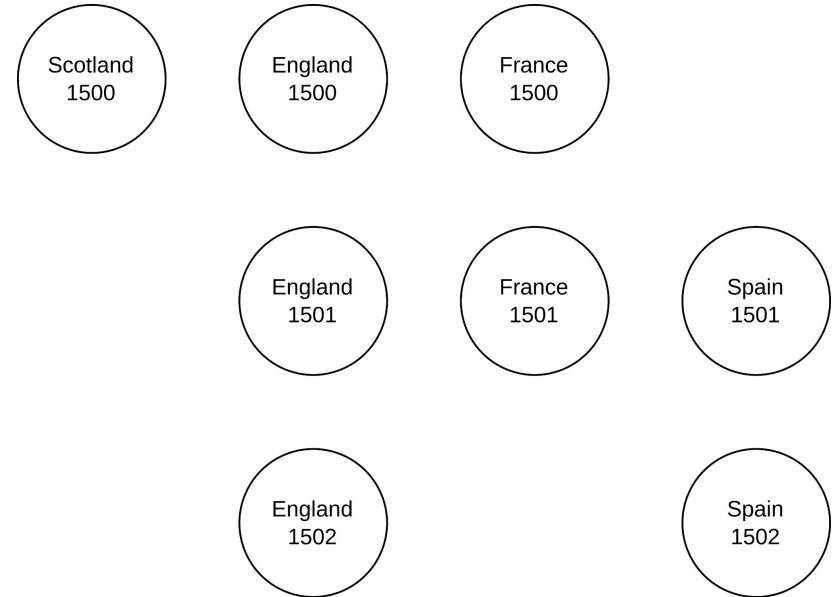
Cultural Social Network

Worked with the organisation Geacron to create a cultural social network (CSN).

Graph that represents links between different countries, cultures or political entities.

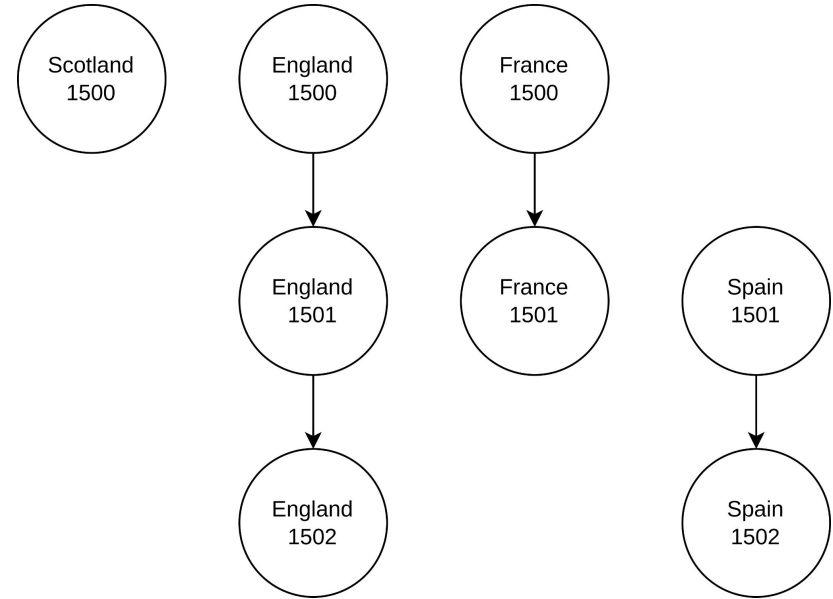
Cultural Social Network Construction

1. A node is added for every country-year pair.



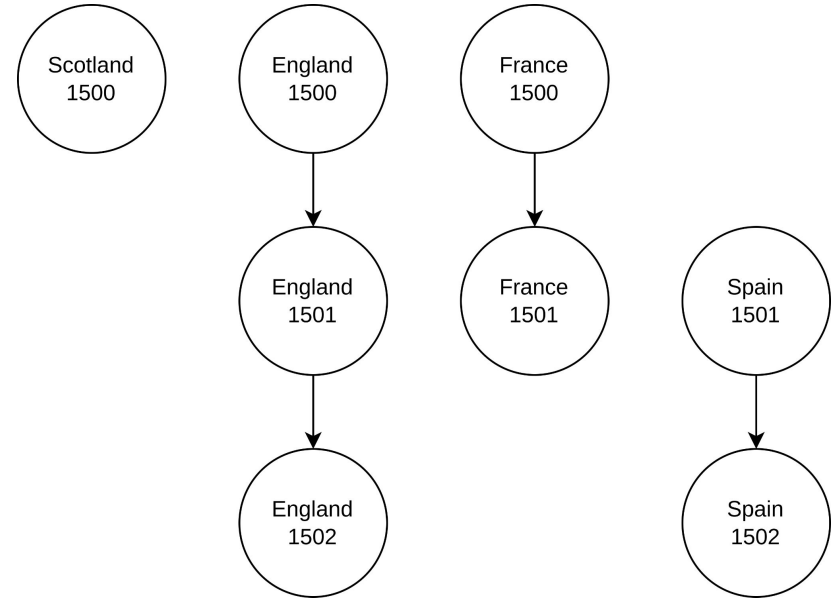
Cultural Social Network Construction

1. A node is added for every country-year pair.
2. Every node points to the node of the same country one year in the future.



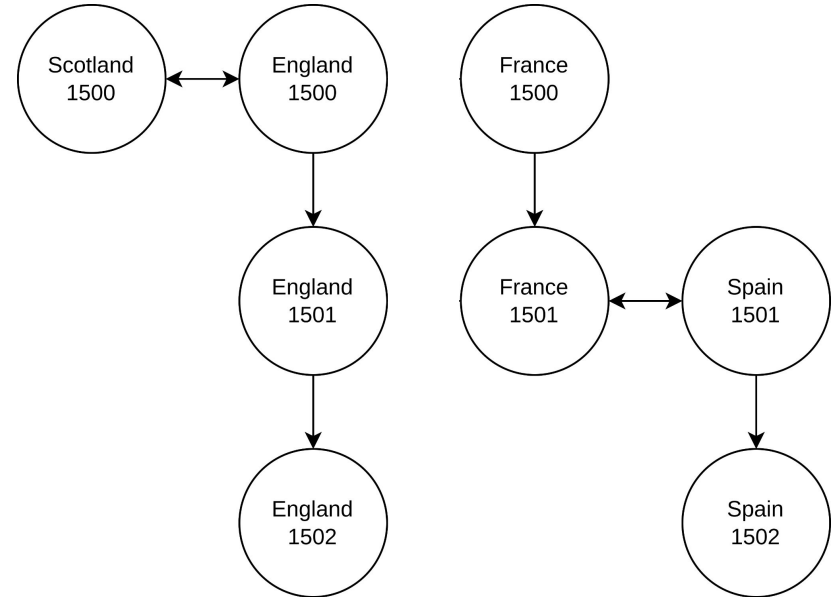
Cultural Social Network Construction

1. A node is added for every country-year pair.
2. Every node points to the node of the same country one year in the future.
3. Every node points to the node of a different country with the same year, if either of the following is true:



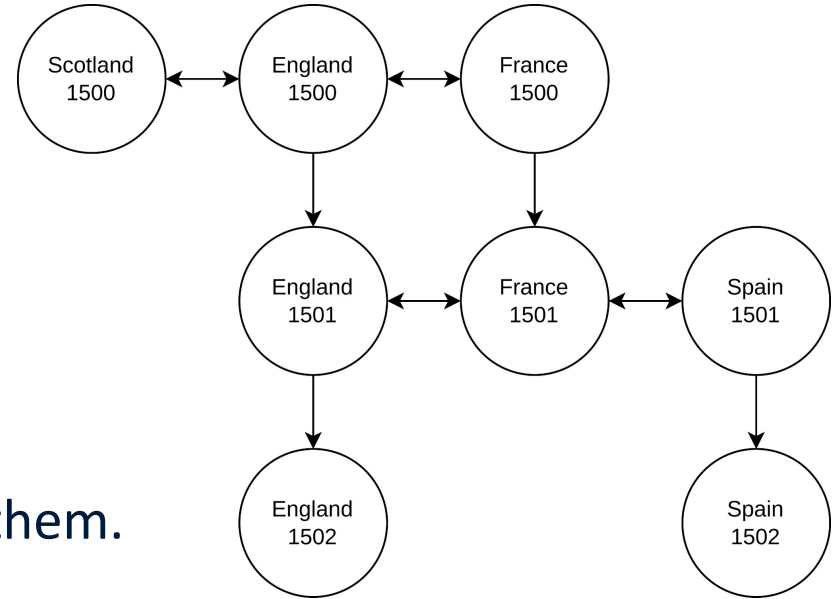
Cultural Social Network Construction

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3. Every node points to the node of a different country with the same year, if either of the following is true:
 - They are adjacent.



Cultural Social Network Construction

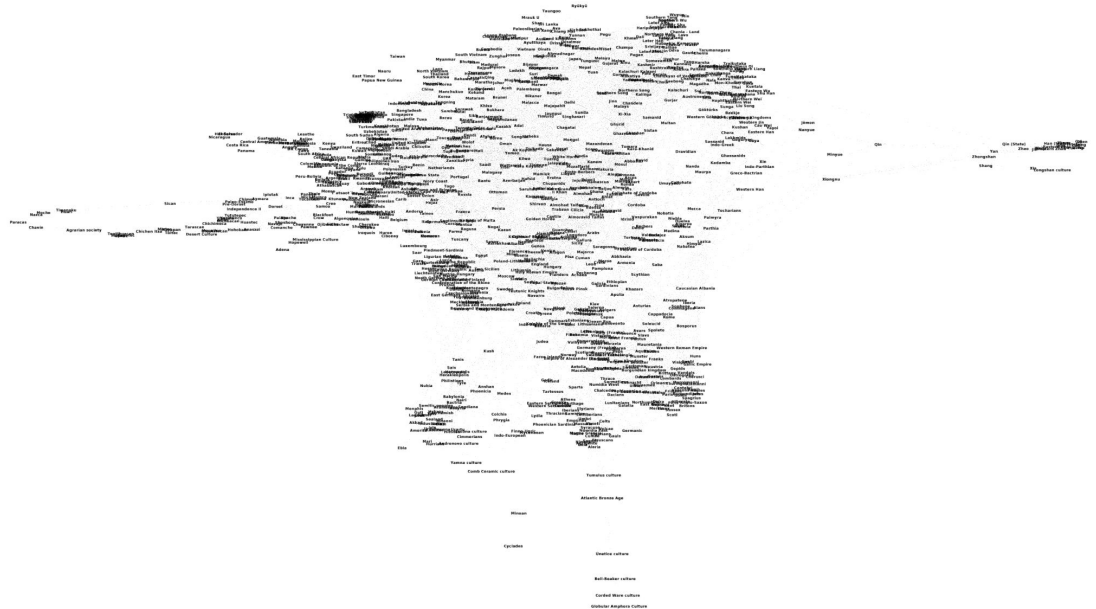
1. A node is added for every country-year pair.
2. Every node points to the node of the same country one year in the future.
3. Every node points to the node of a different country with the same year, if either of the following is true:
 - They are adjacent.
 - They have a known route between them.



Cultural Social Network

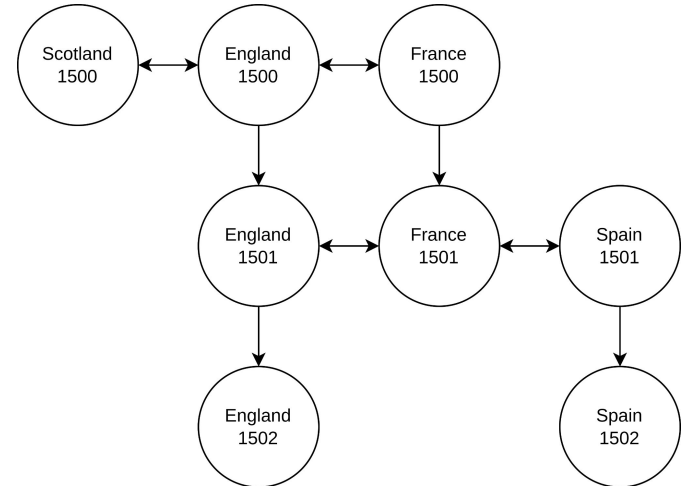
Full network is far too large to show here...

- 412,744 nodes
- 3,472,484 edges



Cultural Distance

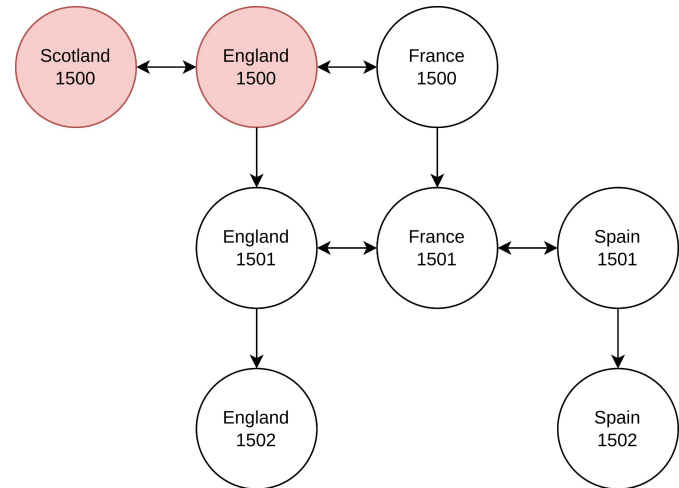
Every game can be associated with a set of nodes based on its geo-temporal evidence data.



Cultural Distance

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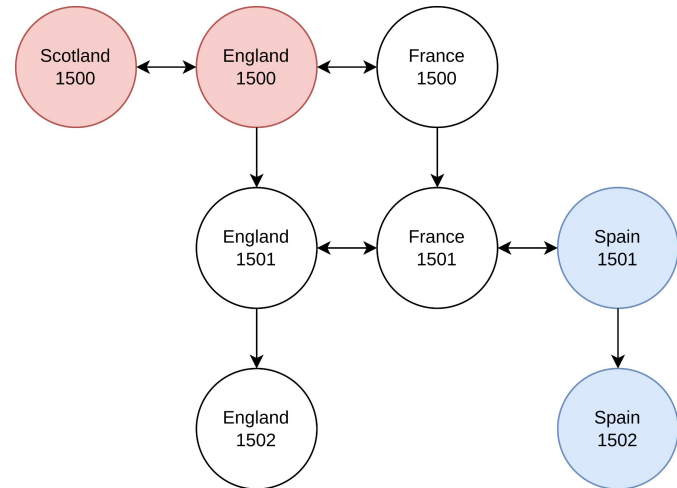
- Game 1: England & Scotland 1500



Cultural Distance

Every game can be associated with a set of nodes based on its geo-temporal evidence data.

- Game 1: England & Scotland 1500
- Game 2: Spain 1501-1502

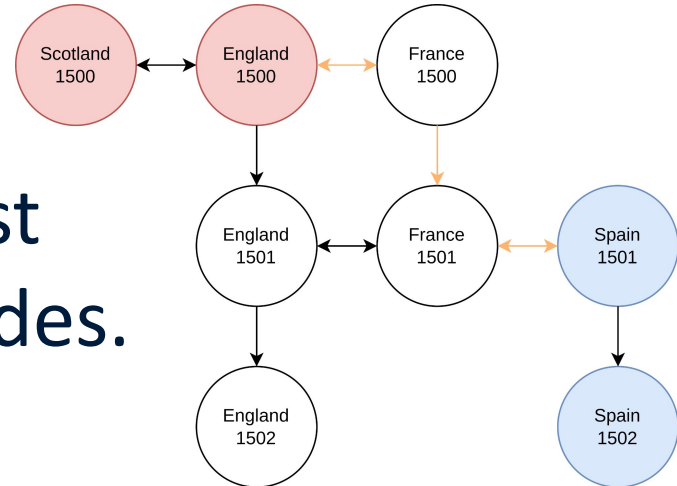


Cultural Distance

Every game can be associated with a set of nodes based on its geo-temporal evidence data.

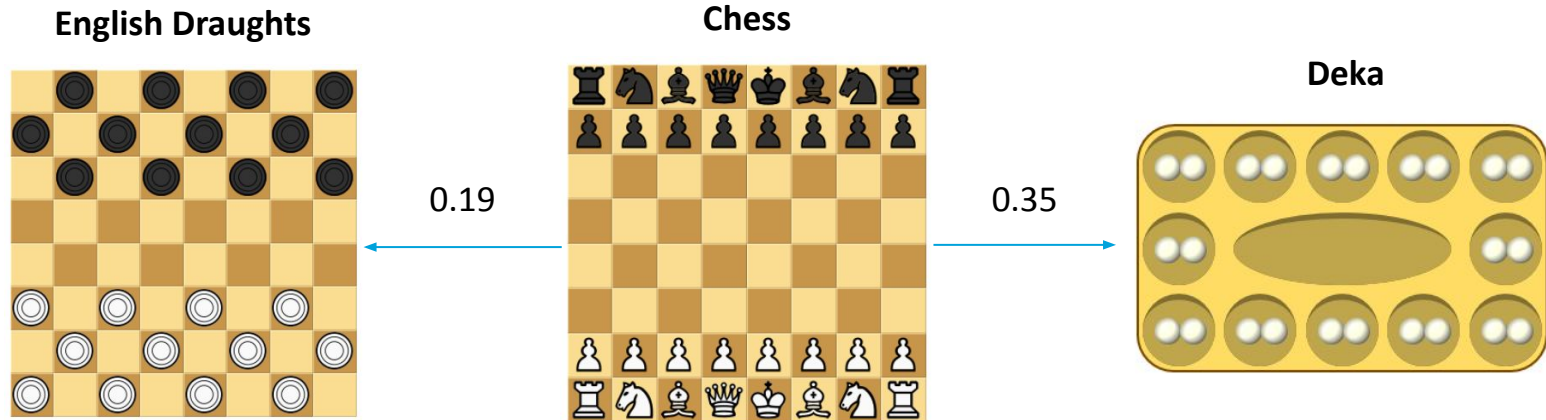
- Game 1: England & Scotland 1500
- Game 2: Spain 1501-1502

Cultural distance is the shortest path between each game's nodes.



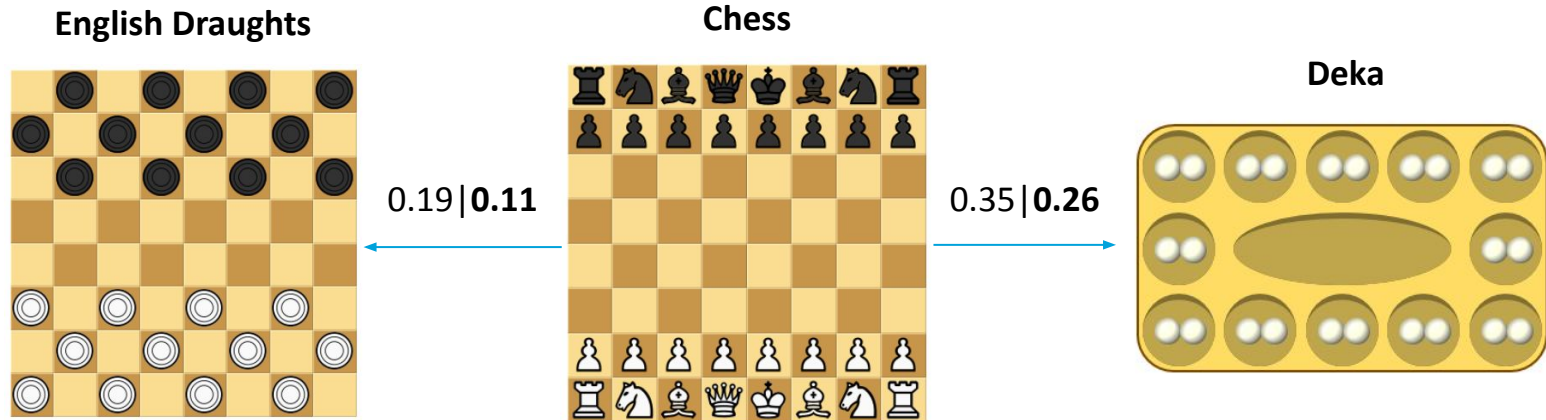
Cultural Distance Example #1

Define measure of distance between two games.



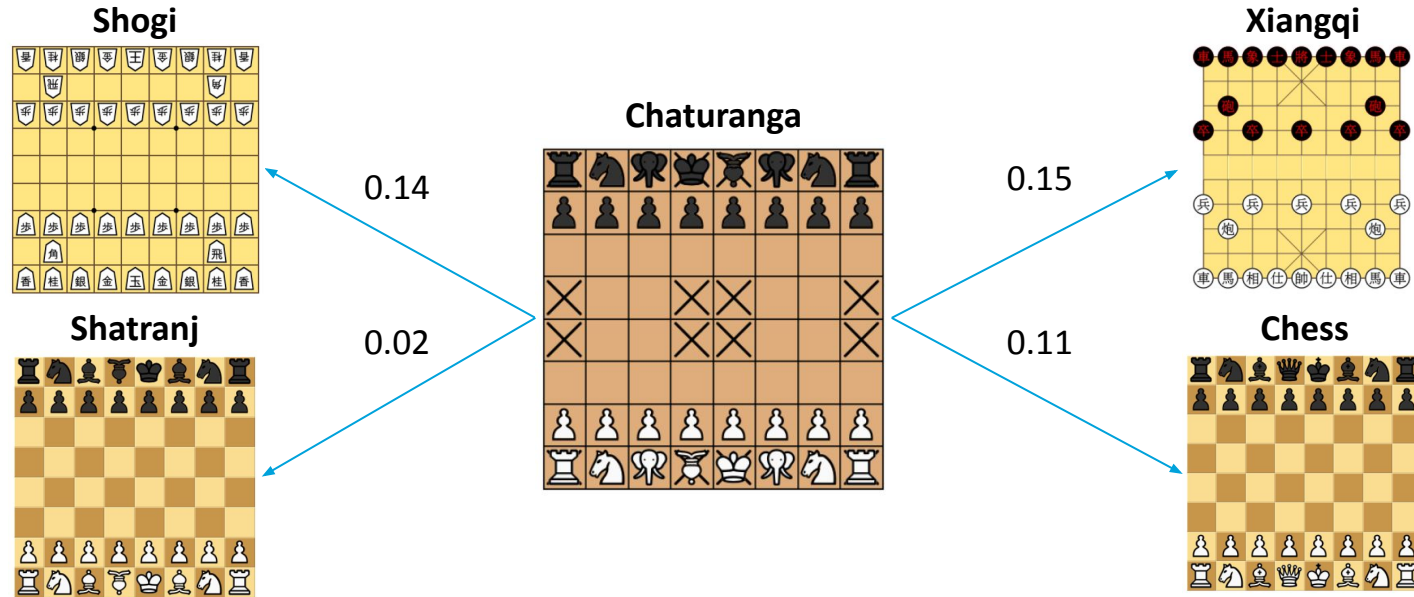
Cultural Distance Example #1

Define measure of distance between two games.



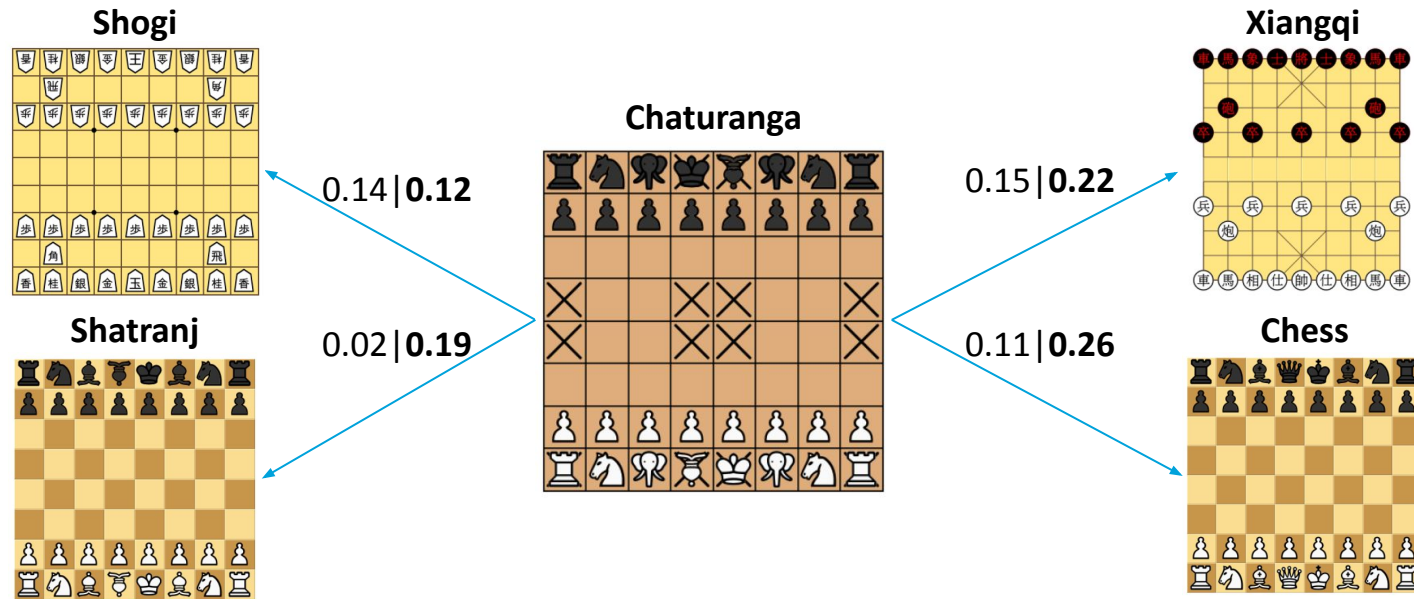
Cultural Distance Example #2

Define measure of distance between two games.



Cultural Distance Example #2

Define measure of distance between two games.



Cultural Distance Applications

Can be used for game reconstruction.



Cultural Distance Applications

Can be used for game reconstruction.

When attempting to reconstruct the rules of a game, take inspiration from nearby examples.



Game Reconstruction

Can be used for game reconstruction.

When attempting to reconstruct the rules of a game, take inspiration from nearby examples.

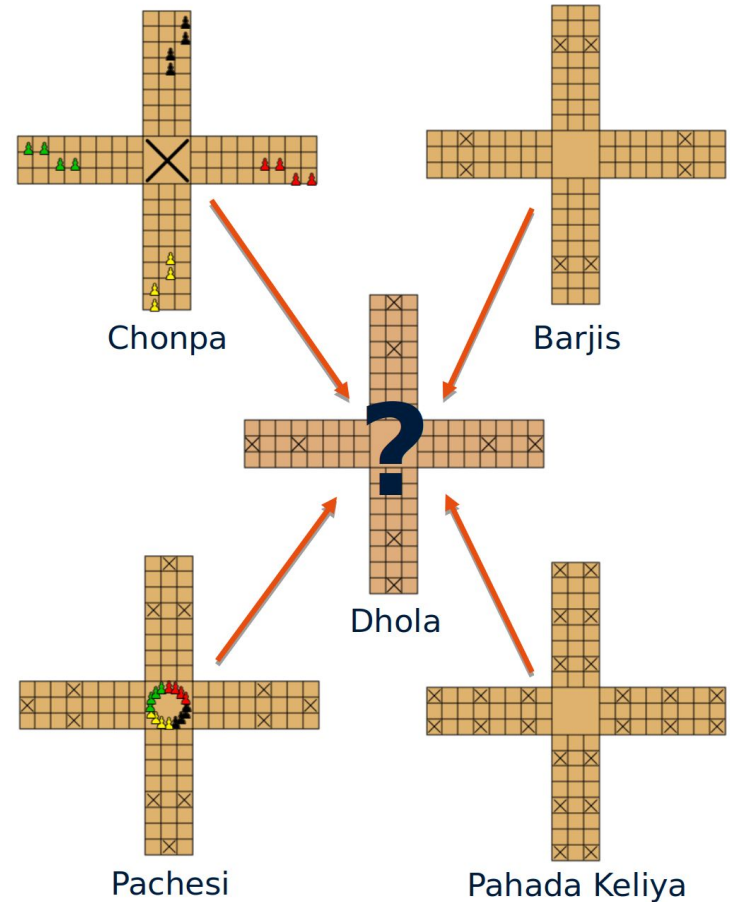
Identify other games with the lowest gameplay and cultural distances (highest similarity).

Reconstruction Example #1

Dhola (~1883_{CE})

Pachisi-style board design.

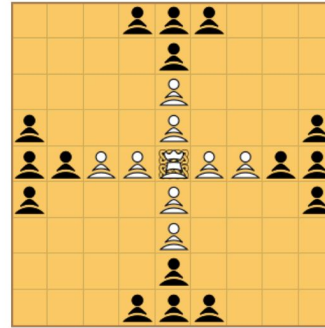
Probably shared many rules and/or equipment with other nearby games.



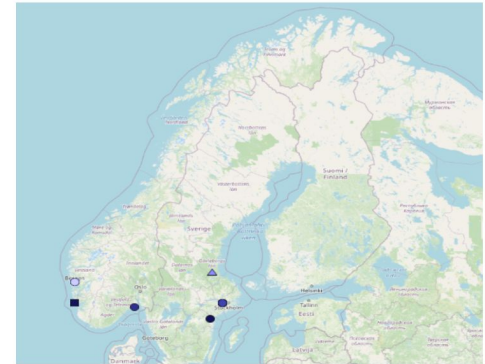
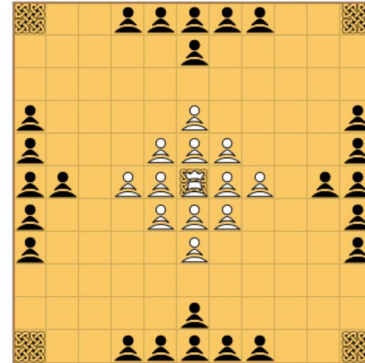
Reconstruction Example #2

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)

What do you think?

What do you think?

How much should gameplay and cultural distance impact our reconstruction process?



What do you think?

How much should gameplay and cultural distance impact our reconstruction process?

Which of these two measures is more important?

What do you think?

How much should gameplay and cultural distance impact our reconstruction process?

Which of these two measures is more important?

Does it make sense to reconstruct historical games in this manner?

Paths

145,44,2612,Start: Gurjar(900) __ Gurjar(1008) -> Byzantium(1008) via Mecca __ Byzantium(1206) -> Papal States(1206) via Ravenna - Greece __ End: Papal States(1512) __ Distance: 2612

145,46,1158,Start: Gurjar(900) __ Gurjar(914) -> Japan(914) via Buddhist pilgrimage __ End: Japan(1058) __ Distance: 1158

145,49,2158,Start: Gurjar(621) __ Gurjar(700) -> Srivijaya(700) via Hinduism expansion __ Srivijaya(779) -> Tang(779) via China - Indian Ocean by Strait of Malacca __ End: Tang(779) __ Distance: 2158

145,306,2030,Start: Gurjar(621) __ Gurjar(651) -> Sassanid(651) via North India - Center __ Sassanid(651) -> Caliphate(651) via Silk Road __ End: Caliphate(651) __ Distance: 2030

44,56,1022,Start: Papal States(1512) __ Papal States(1534) -> France(1534) via Western Venetian Route __ End: France(1534) __ Distance: 1022

44,69,1415,Start: Papal States(1512) __ Papal States(1797) -> United Kingdom(1797) via Western Venetian Route __ End: United Kingdom(1927) __ Distance: 1415

306,44,1364,Start: Byzantium(1148) __ Byzantium(1206) -> Papal States(1206) via Ravenna - Greece __ End: Papal States(1512) __ Distance: 1364

306,46,1458,Start: Western Göktürks(600) __ Western Göktürks(600) -> Japan(600) via Buddhism expansion __ End: Japan(1058) __ Distance: 1458

306,49,1028,Start: Abbasid(751) __ Abbasid(779) -> Tang(779) via Silk Road __ End: Tang(779) __ Distance: 1028

306,145,1017,Start: Sassanid(604) __ Sassanid(621) -> Gurjar(621) via North India - Center __ End: Gurjar(621) __ Distance: 1017

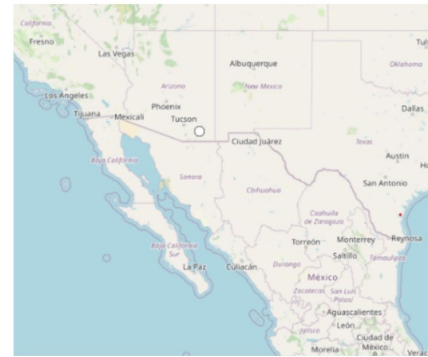
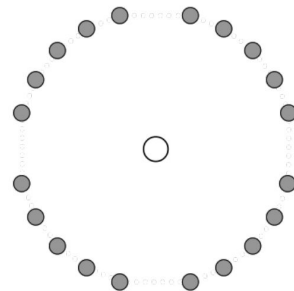


Reconstruction Example #3

Apache game based on archaeological evidence.

All known games with a similar board used dice.

Highly likely that this game also used dice.

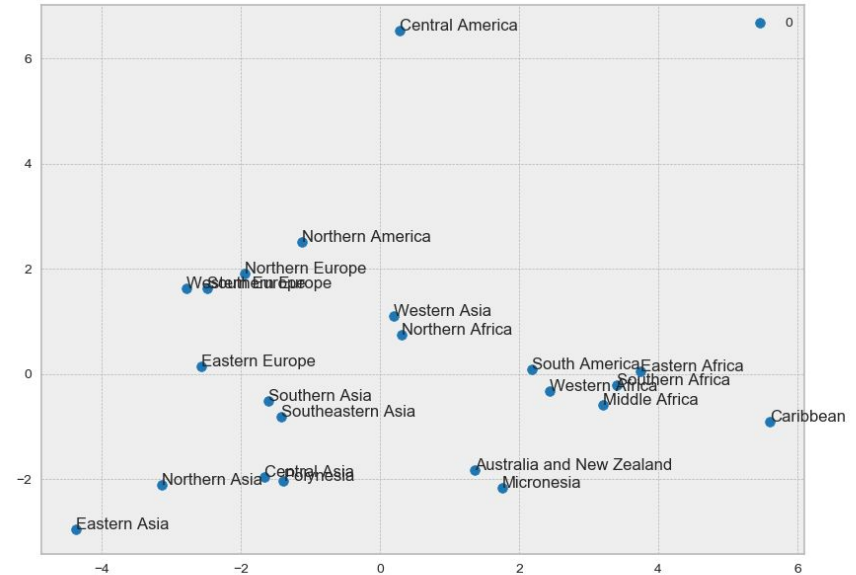
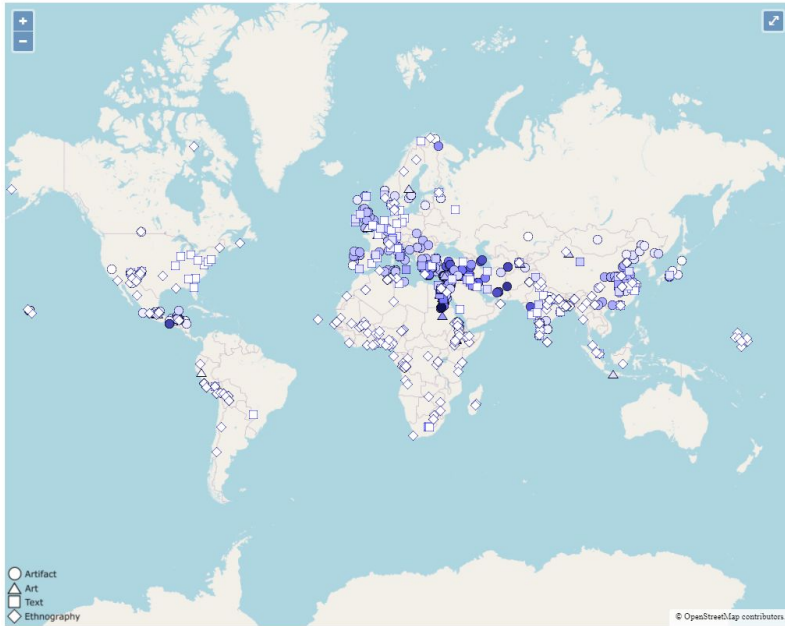


Ancestral Apache Game (1280 - 1580CE)



Game Clustering

Measure game similarity between different regions.



Gameplay Distance

Calculate distance between two games based on how different their gameplay properties are.

Several possible ways to calculate this:

- Cosine, Jensen–Shannon, Euclidean, Manhattan, etc.

Different features may be weighted differently

- Term frequency, Inverse document frequency, etc.

Cultural Distance Applications

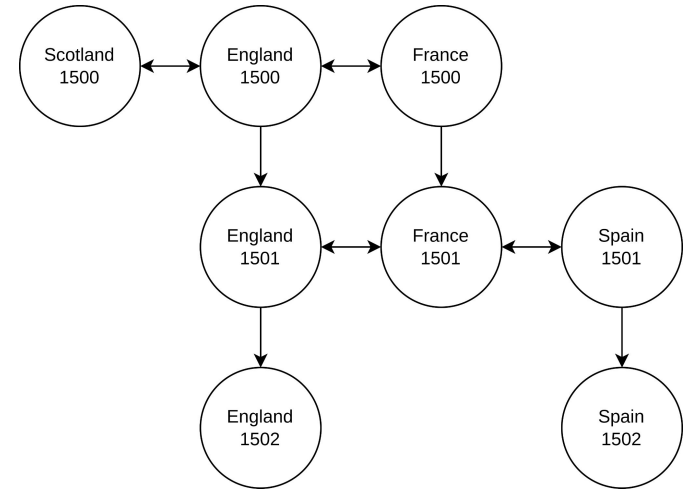
Can be used to identify possible links or paths between games based on their evidence.

Chaturanga -> Shatranj

- Gurjar (621) -> Gurjar (651)
- Gurjar (651) -> Sassanid (651), via Northern India route
- Sassanid (651) -> Caliphate (651), via Silk Road

Network Edge Weighting

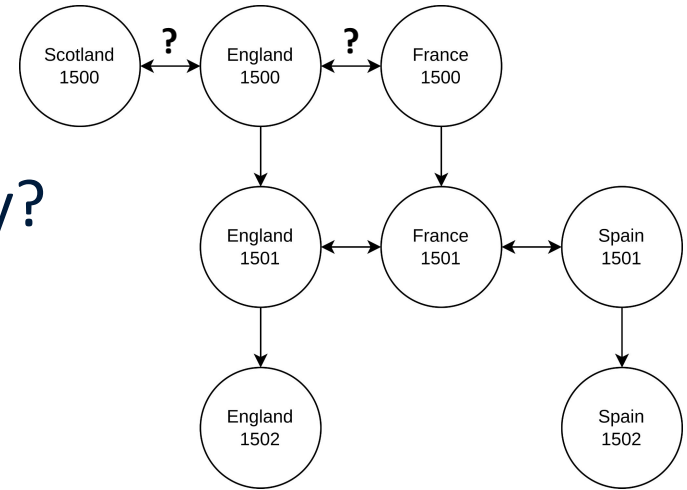
Should all edges in our cultural social network be weighted the same?



Network Edge Weighting

Should all edges in our cultural social network be weighted the same?

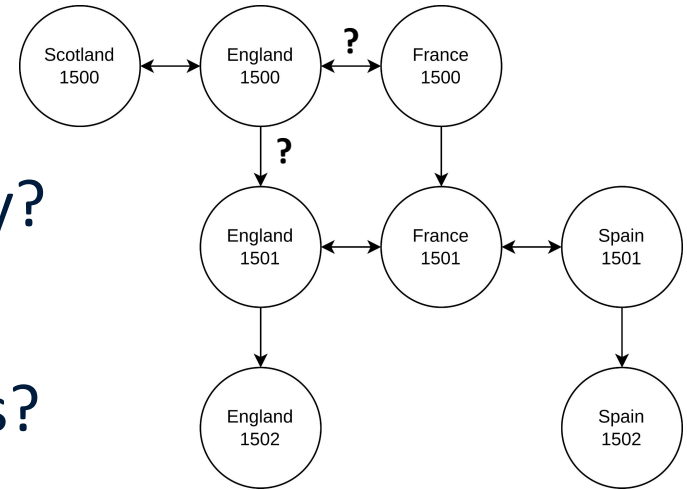
- Are connections from trade routes as important as those of direct adjacency?



Network Edge Weighting

Should all edges in our cultural social network be weighted the same?

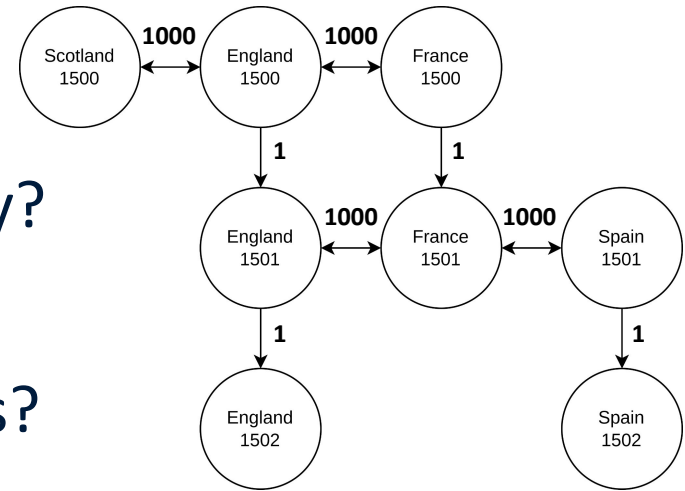
- Are connections from trade routes as important as those of direct adjacency?
- Are connections between years as important as those between countries?



Network Edge Weighting

Should all edges in our cultural social network be weighted the same?

- Are connections from trade routes as important as those of direct adjacency?
- Are connections between years as important as those between countries?
- How many years equals an country change?



Gameplay Properties

Obtained from the Ludii software.

- Ludemes
- Concepts
- Metrics
- AI performance

Random:	8%
Alpha Beta:	37%
UCT:	71%
UCT (Uncapped):	66%
MC-Grave:	62%
Flat MC:	45%
MAST:	22%
Progressive History:	48%
Bandit Tree Search:	14%
Biased MCTS:	57%
BRS+:	23%