

# Designing Consensus: Gamified Modeling and Simulation of Collaborative Decision-Making

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IAP 2025 (Non-Credit)

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<b>Jan 21</b>	<b>Modeling and Collaborative Decision-Making</b>	<ul style="list-style-type: none"><li>• Further introduction to game theory and decision-making from a computational perspective.</li><li>• Explore how we can turn a game (like Go) into a format the computer can recognize, play, and learn with. A touch on PettingZoo as a standard for creating digital environments.</li><li>• A brief introduction to traditional decision-making modeling approaches, such as behavioral trees, finite state machines, and rule-based systems.</li></ul>
	<b>Workshop</b>	<ul style="list-style-type: none"><li>• Group formation, mockups, playtesting, and refinement of your conceptual board game.</li><li>• Free food will be provided to celebrate my birthday!</li></ul>

# Welcome



<https://forms.gle/22t7YViqMT1aLWYs9>

Interest Form and Mail List

For online folks, the class will begin at 6:30



美食才是第一生产力

*Free Food is the 1<sup>st</sup> productive forces*

# Decision making – a skill I wish I have



Make one decision



# Make one decision – Strategies?



Guess the answer:  
Heuristic Decision Making

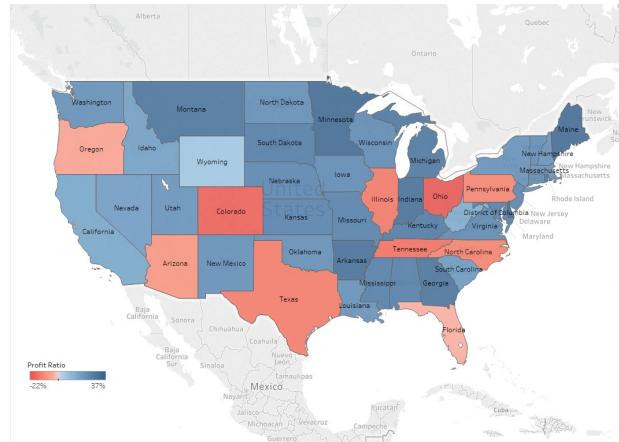


Greedy :  
Analytical Decision-Making

# Before making a (analytical) decision, what info do we need?

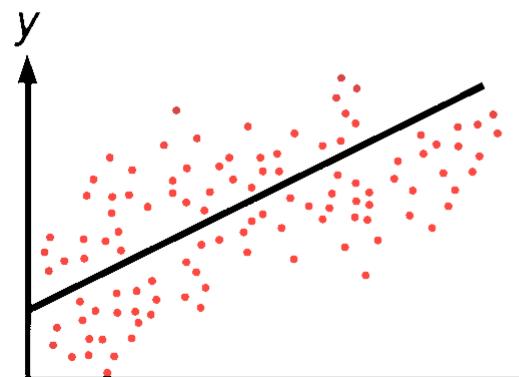
## Descriptive

**What happened?**



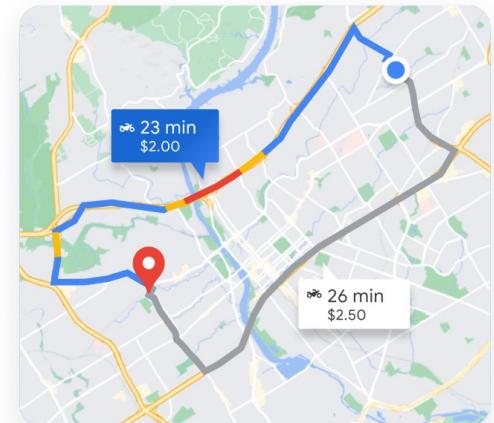
## Predictive

**What will happen?**



## Prescriptive

**What should I do?**



Data Management  
Data Visualization

Forecasting  
Machine Learning

Types of Analysis

Optimization  
Simulation

# After analytics, gather them using **analytical tools**

	Competency	Cost	Viability	Desirability	Alignment	Total
Criteria rating	3	4	5	4	2	
Idea A	1	3	3	1	1	
Weighted rating	3	12	15	4	2	36
Idea B	5	3	5	3	4	
Weighted rating	15	12	25	12	8	72
Idea C	1	2	3	1	1	
Weighted rating	3	8	15	4	2	32
Idea D	5	1	2	1	1	
Weighted rating	15	4	10	4	2	35

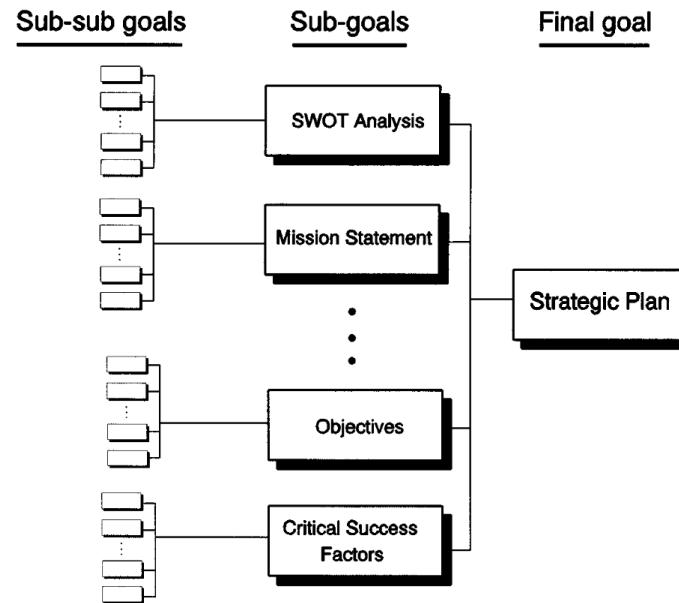
+



## SWOT Analysis

Decision matrices

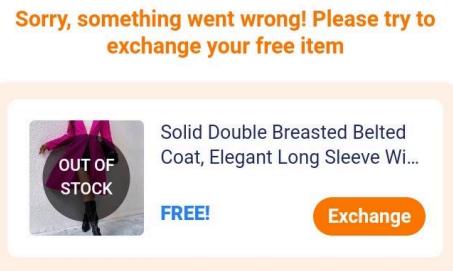
## Strategic Plan Construction



Goal-oriented view of strategic planning

# Analytical Factors

Online shopping as an example



Stock

Budget

Demand

Time pressure

Information Gap

Deterministic

Non-Deterministic

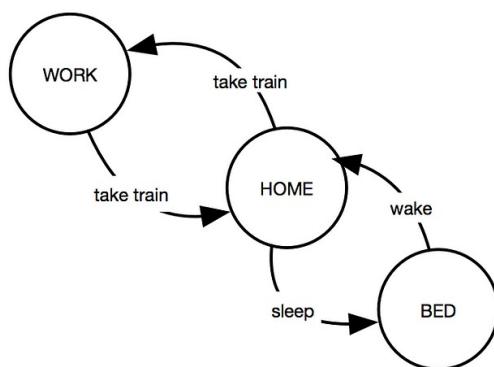
All can be modeled, with more complexity

# Decision Making System in TV Games (not modern AI yet!)

IF HP < 0:  
DIE

IF SEE PLAYER:  
ATTACK

IF NO PLAYER:  
PATROL

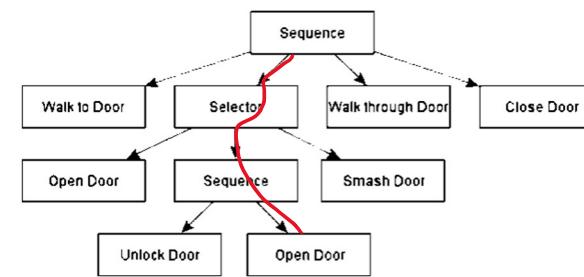


Basic AI

if else ... if else ... if else ...

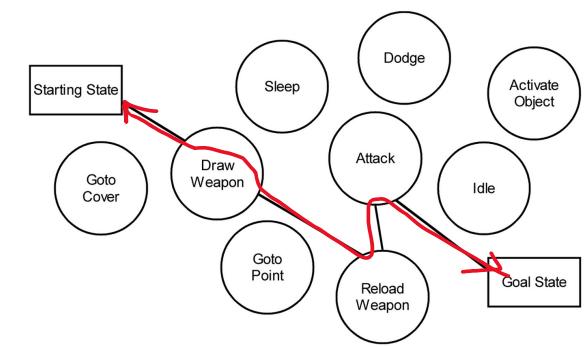
Finite State Machine

abstracts an NPC's behavior into **states**



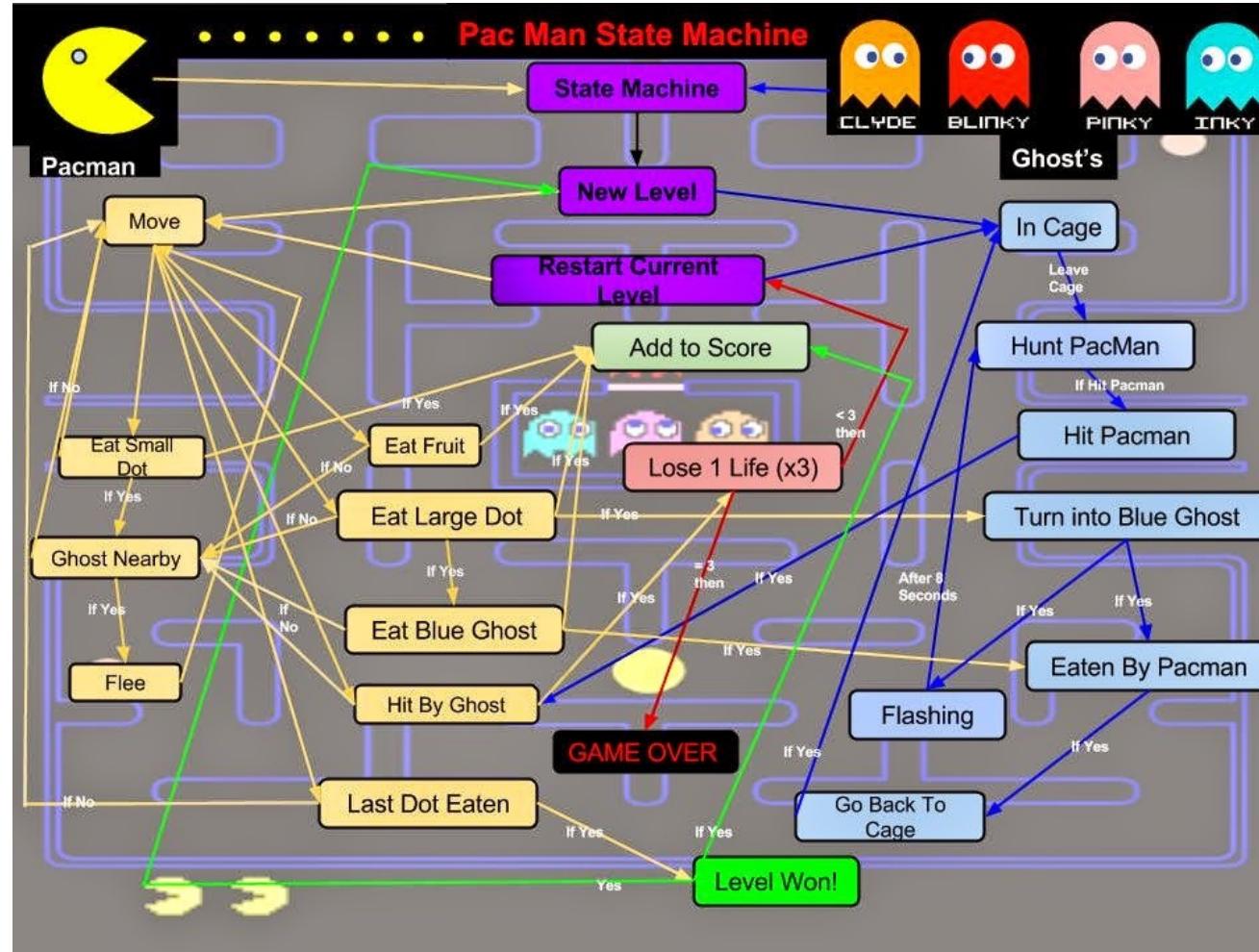
Behavior Tree

Traverse the tree each time to find the best fit

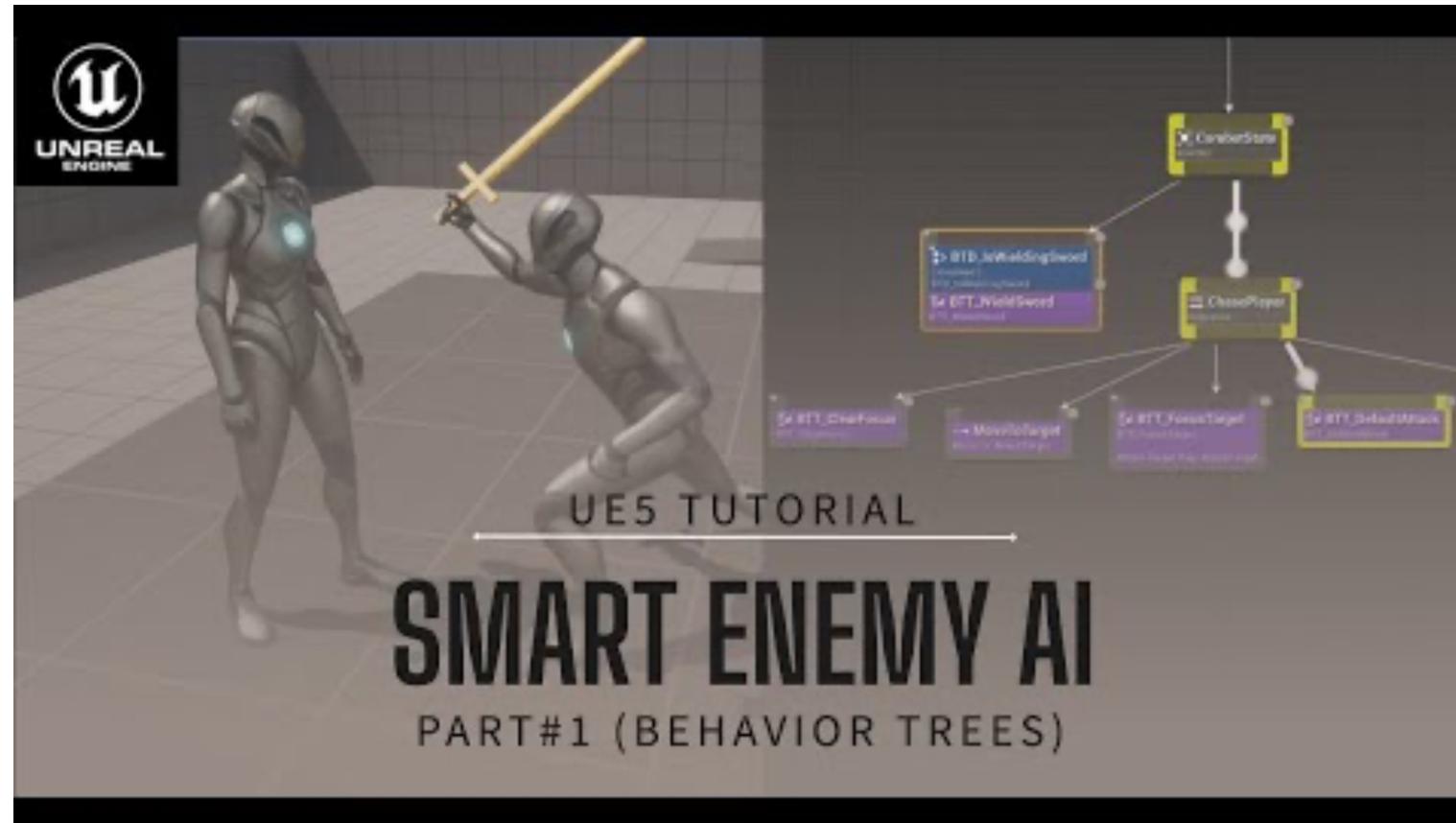


Goal-Oriented Action Planning

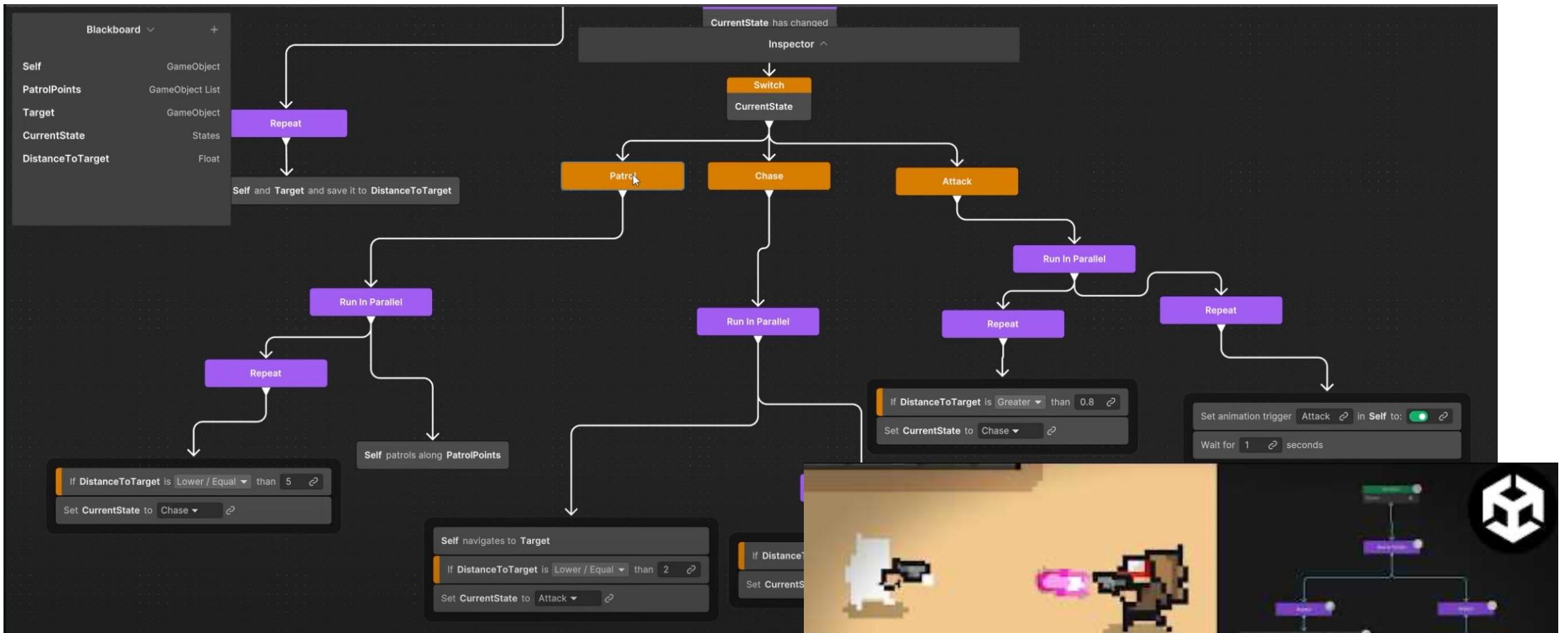
# Finite State Machine in Pacman



# Behavior Tree in Game Engines (Unreal Here)

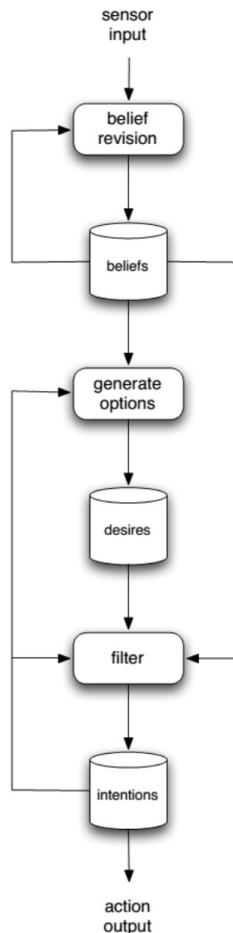


44' - 45'

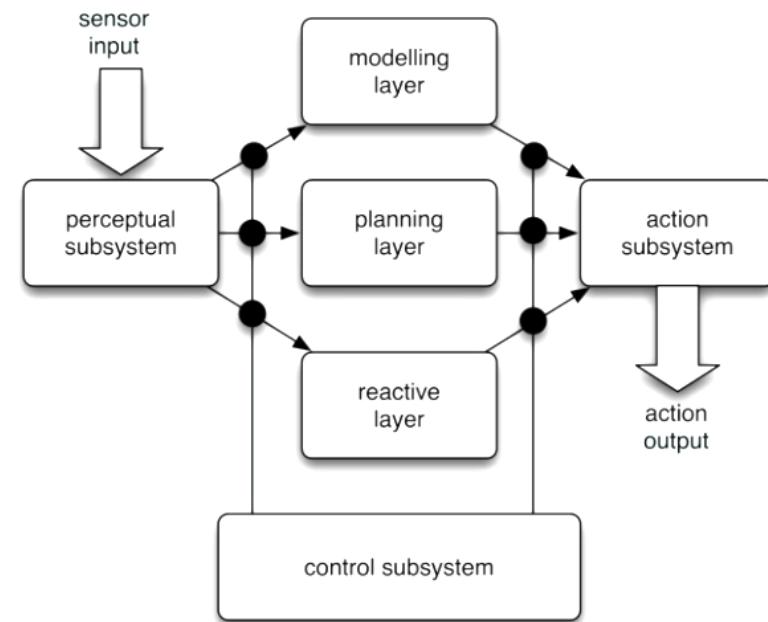


15' - 17'

# Classic Decision Making Architectures

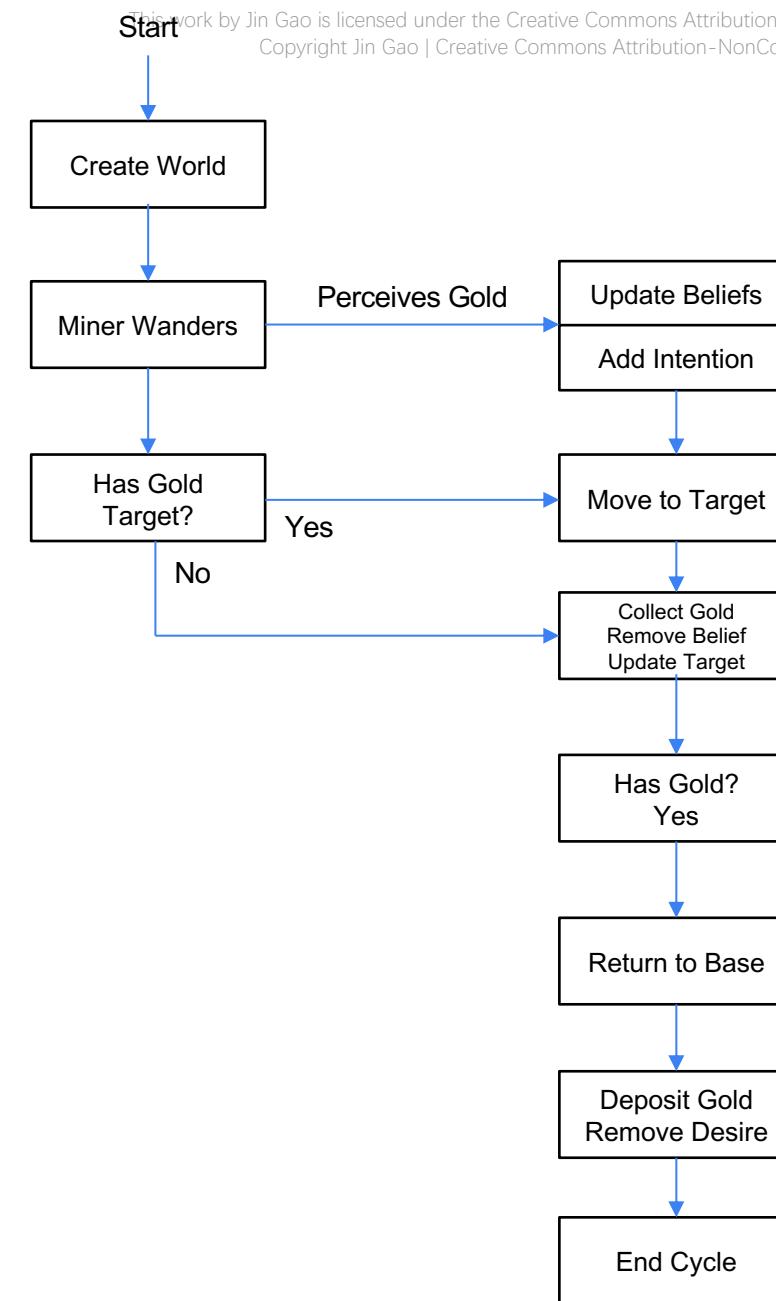
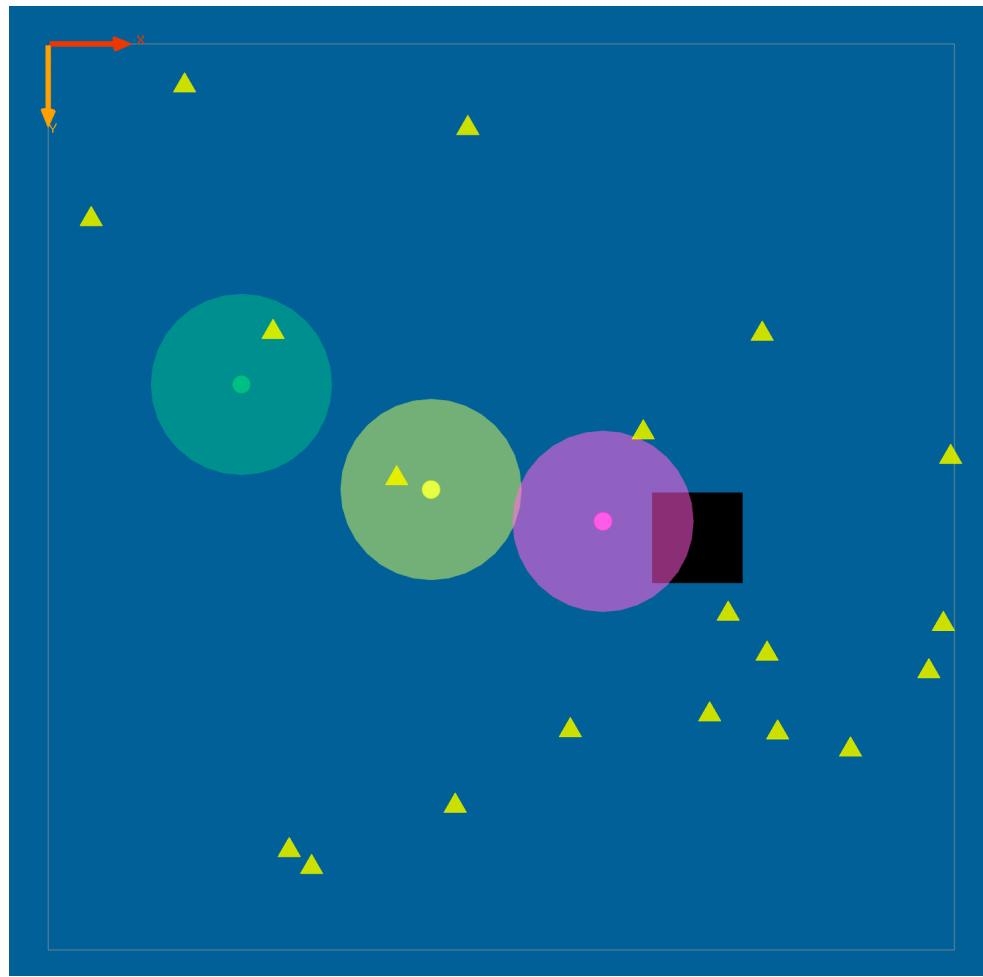


Belief – Desire - Intentions  
(BDI)



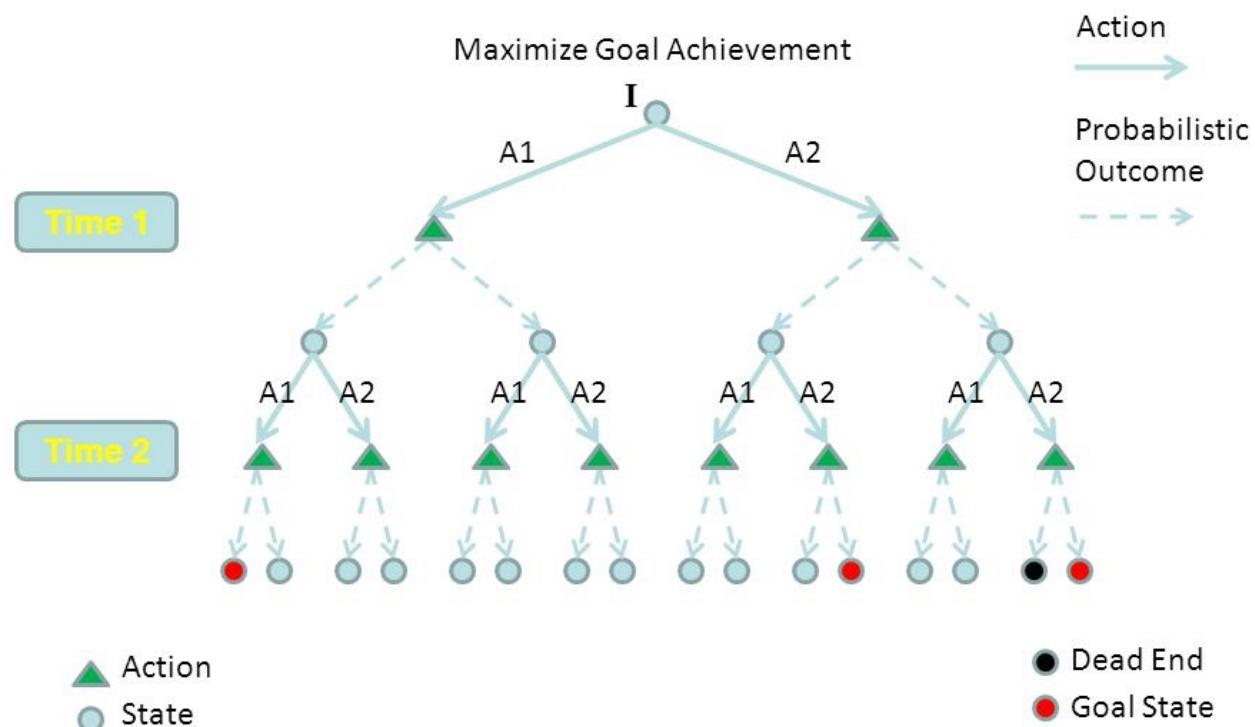
Brook subsumption architecture

# BDI in practice: Gold Miner



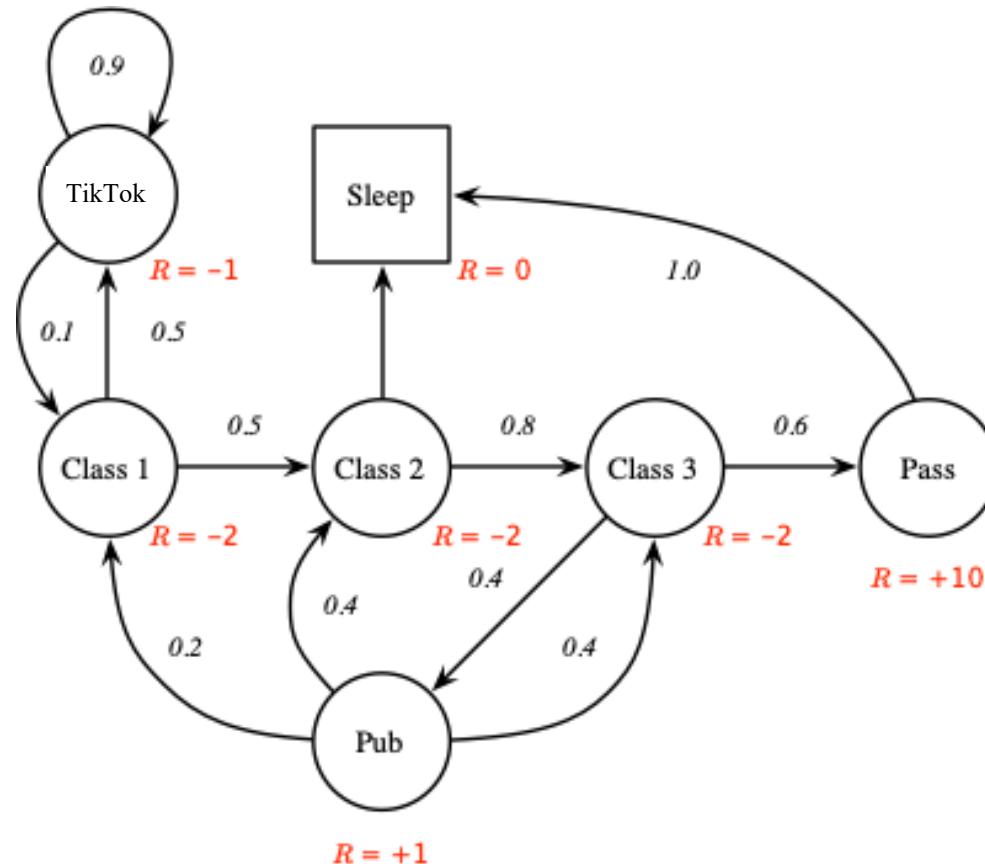
# Probabilistic Planning

(goal-oriented)

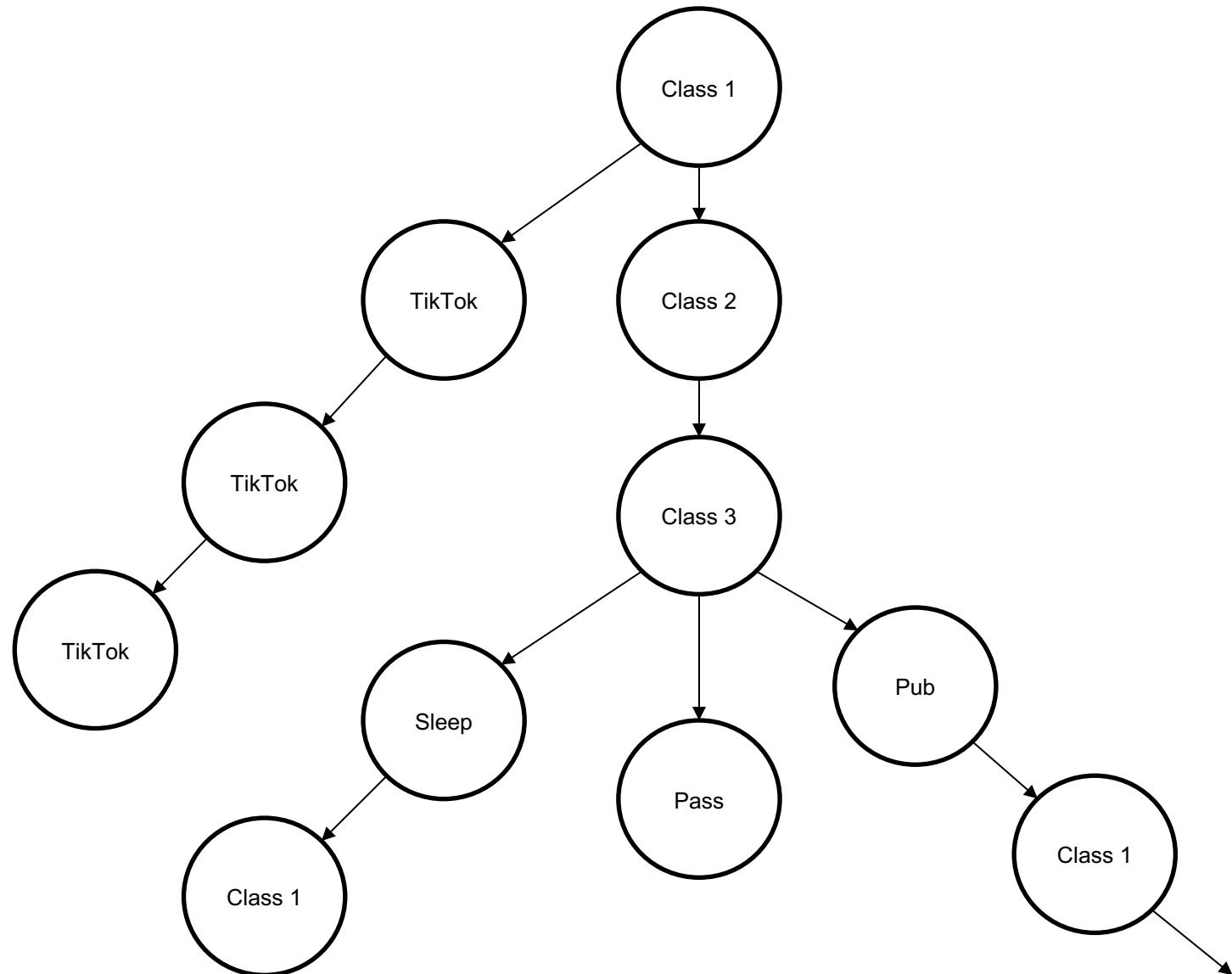
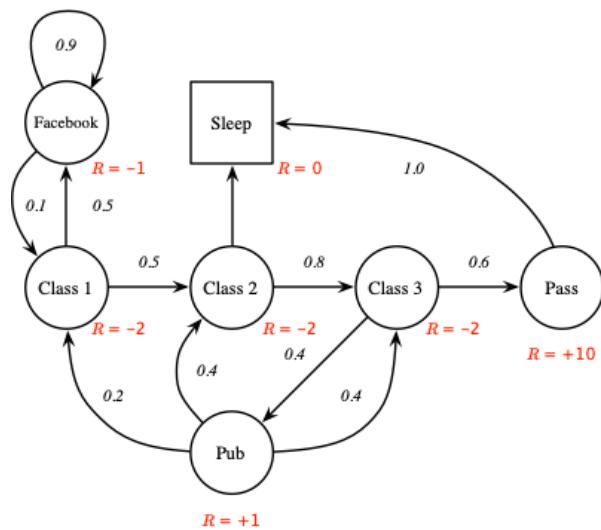


# From Instant Decision to Long-Term Consideration

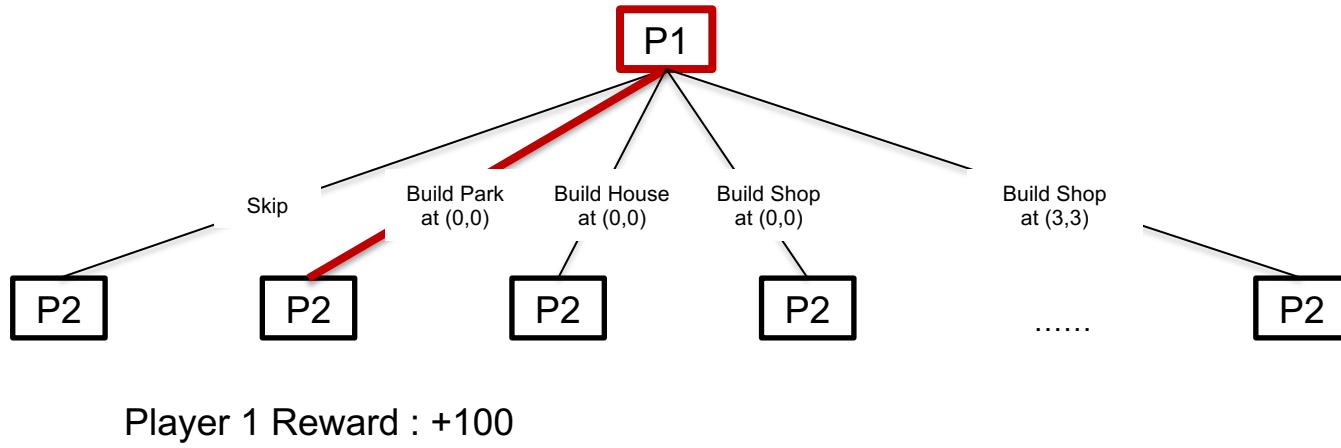
## Markov Decision Process



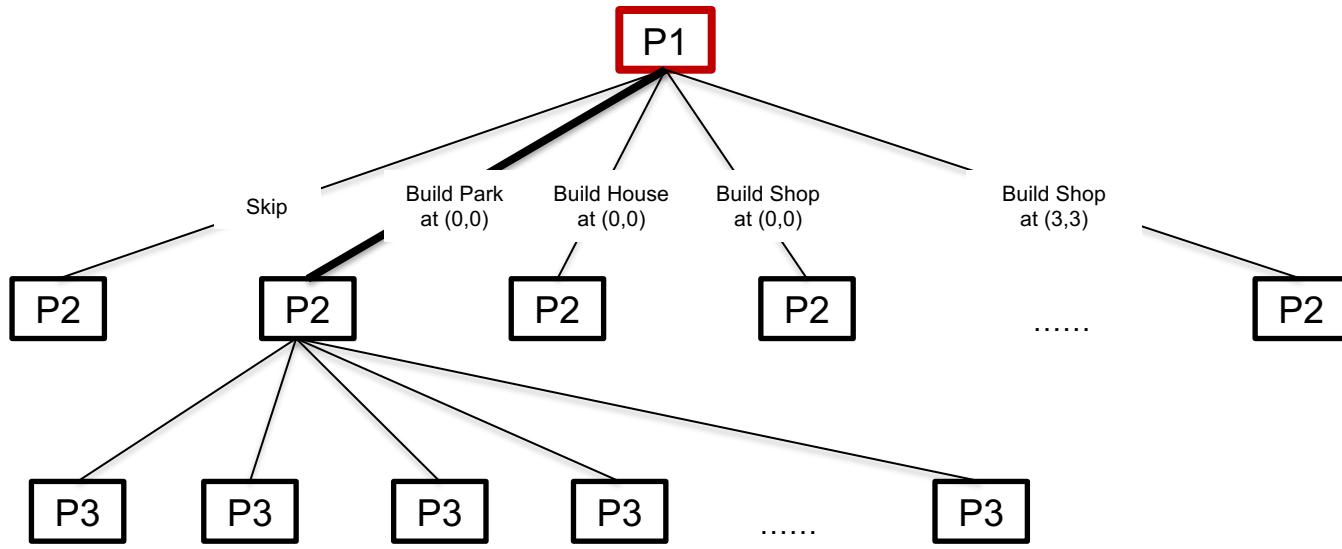
# Expand MDP to Tree Form Decision Process



# Intuition of making a series of decisions From Player 1's Perspective



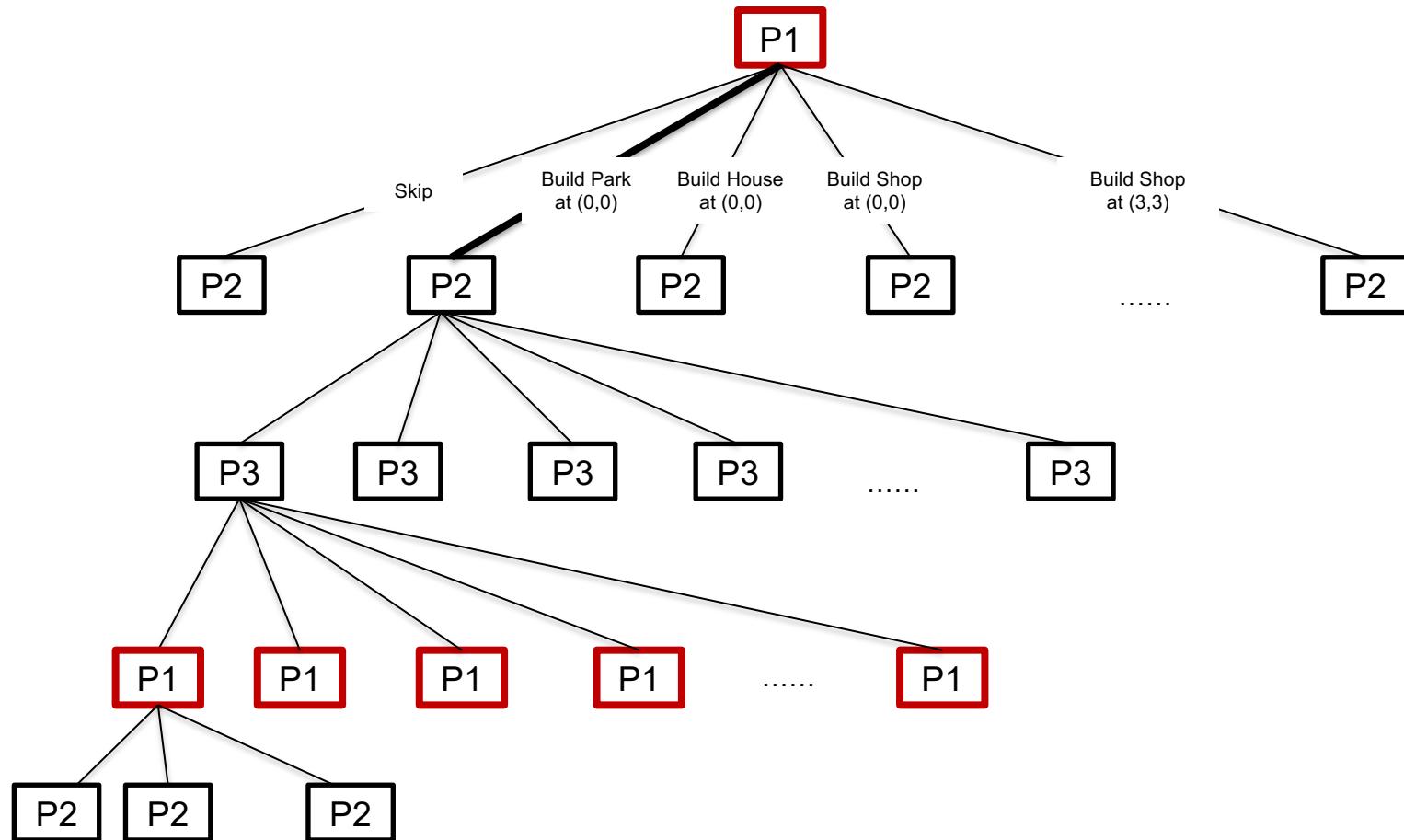
# Intuition of making a series of decisions From Player 1's Perspective



Tree-form Decision Process (TFDP)

# Intuition of making a series of decisions

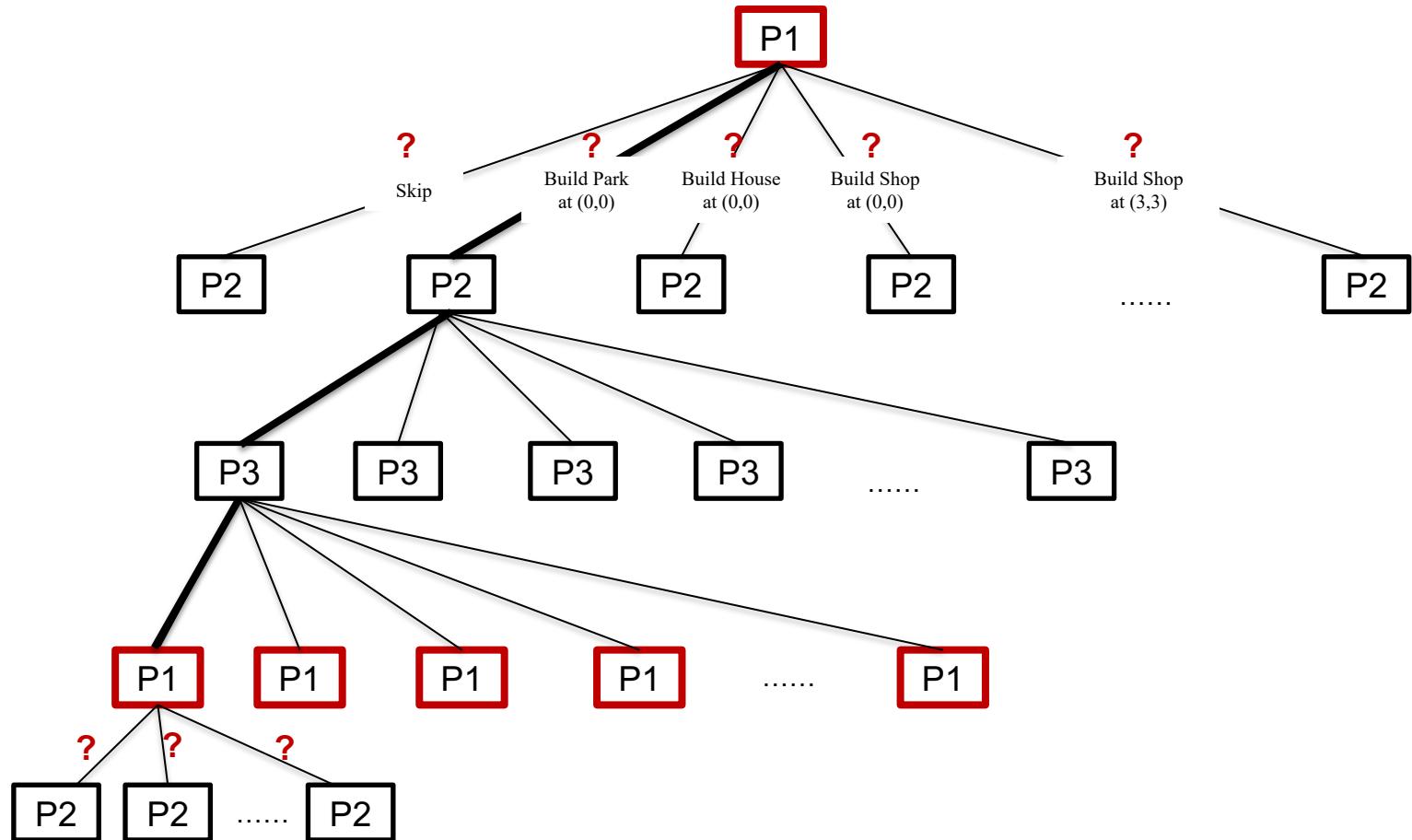
From Player 1's Perspective



Tree-form Decision Process (TFDP)

# Intuition of making a series of decisions

From Player 1's Perspective



Tree-form Decision Process (TFDP)

# Plotting Decisions with Hidden Information: Game Tree vs Tree Form Decision Process

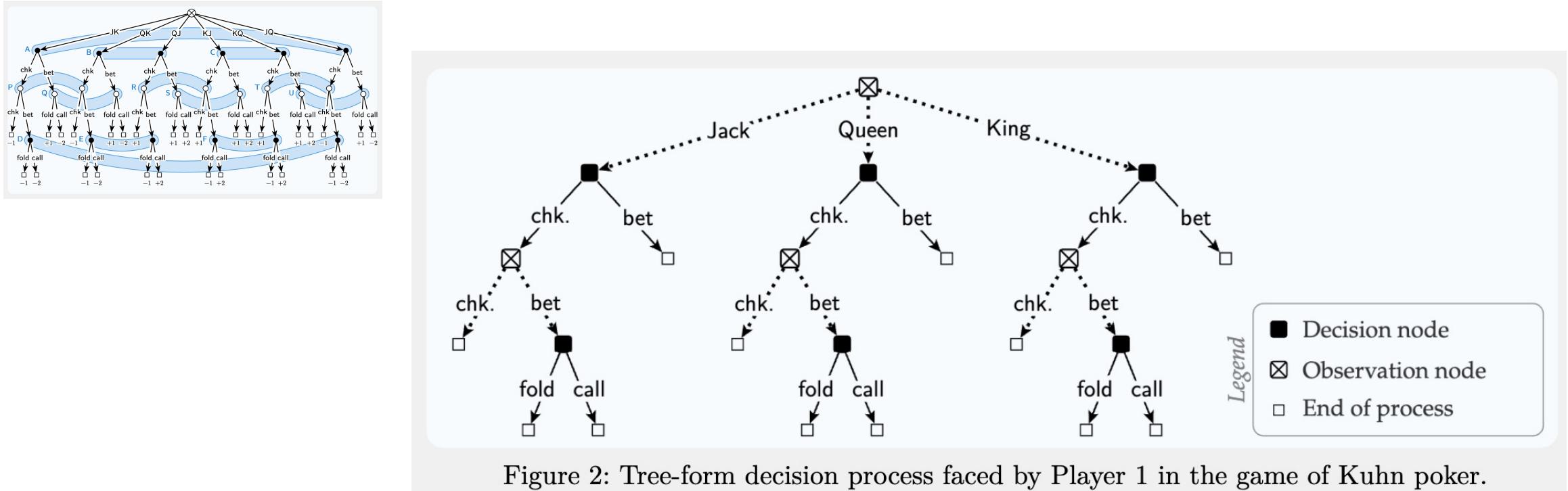
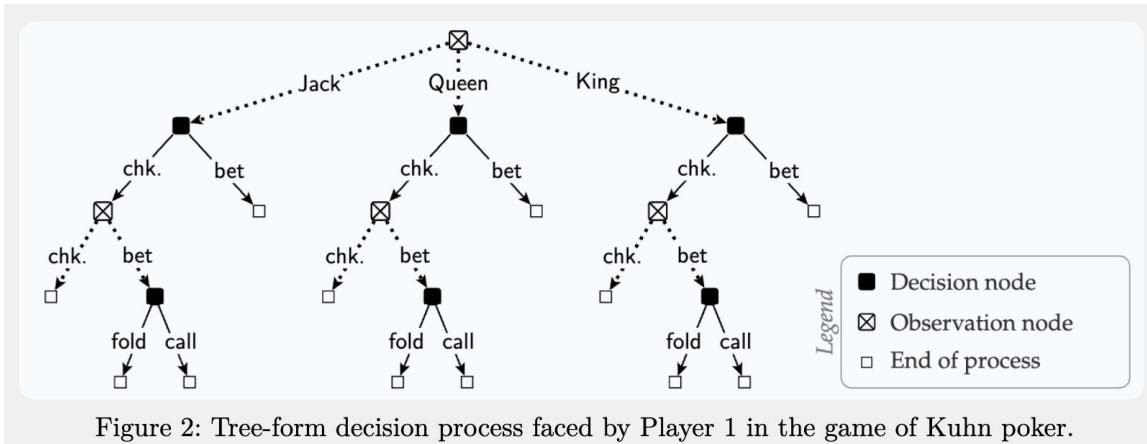


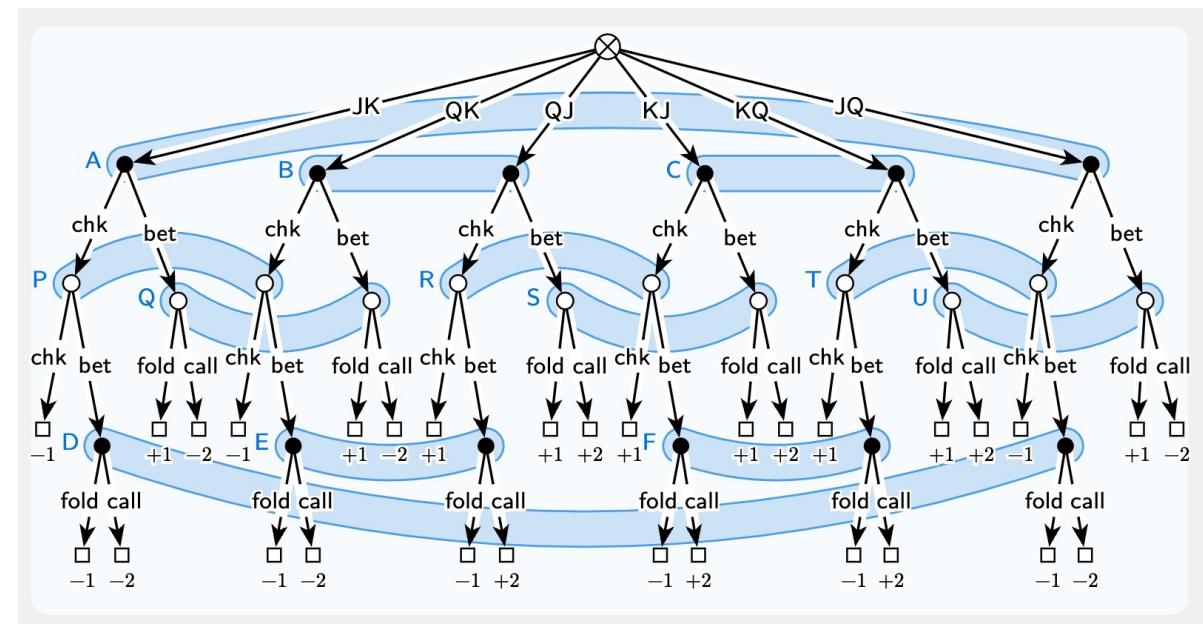
Figure 2: Tree-form decision process faced by Player 1 in the game of Kuhn poker.

Decision Tree

# Plotting Decisions with Hidden Information: Game Tree vs Tree Form Decision Process

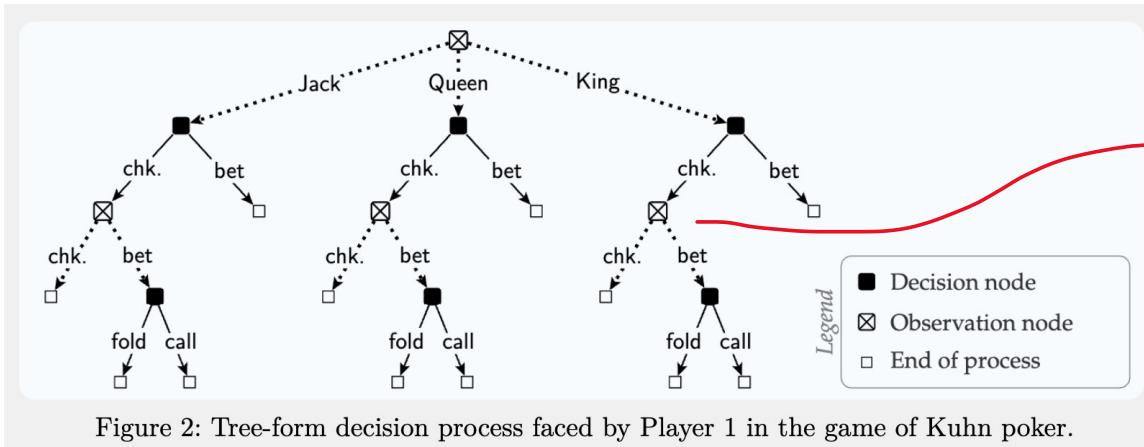


Decision Tree

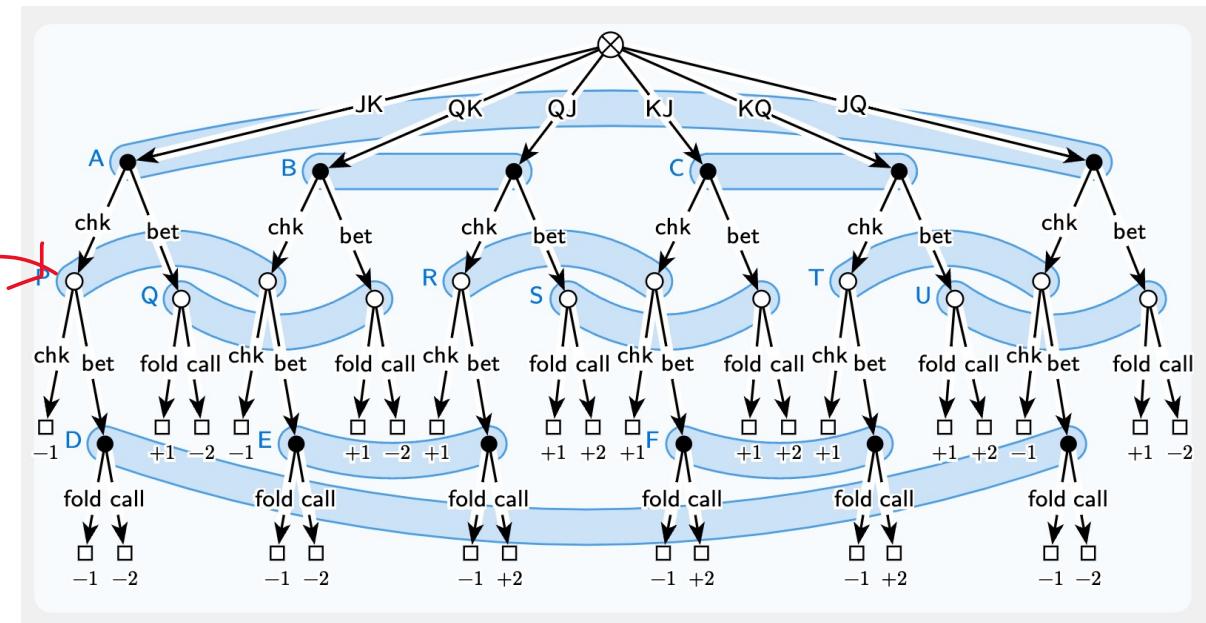


Game Tree

# Plotting Decisions with Hidden Information: Game Tree vs Tree Form Decision Process

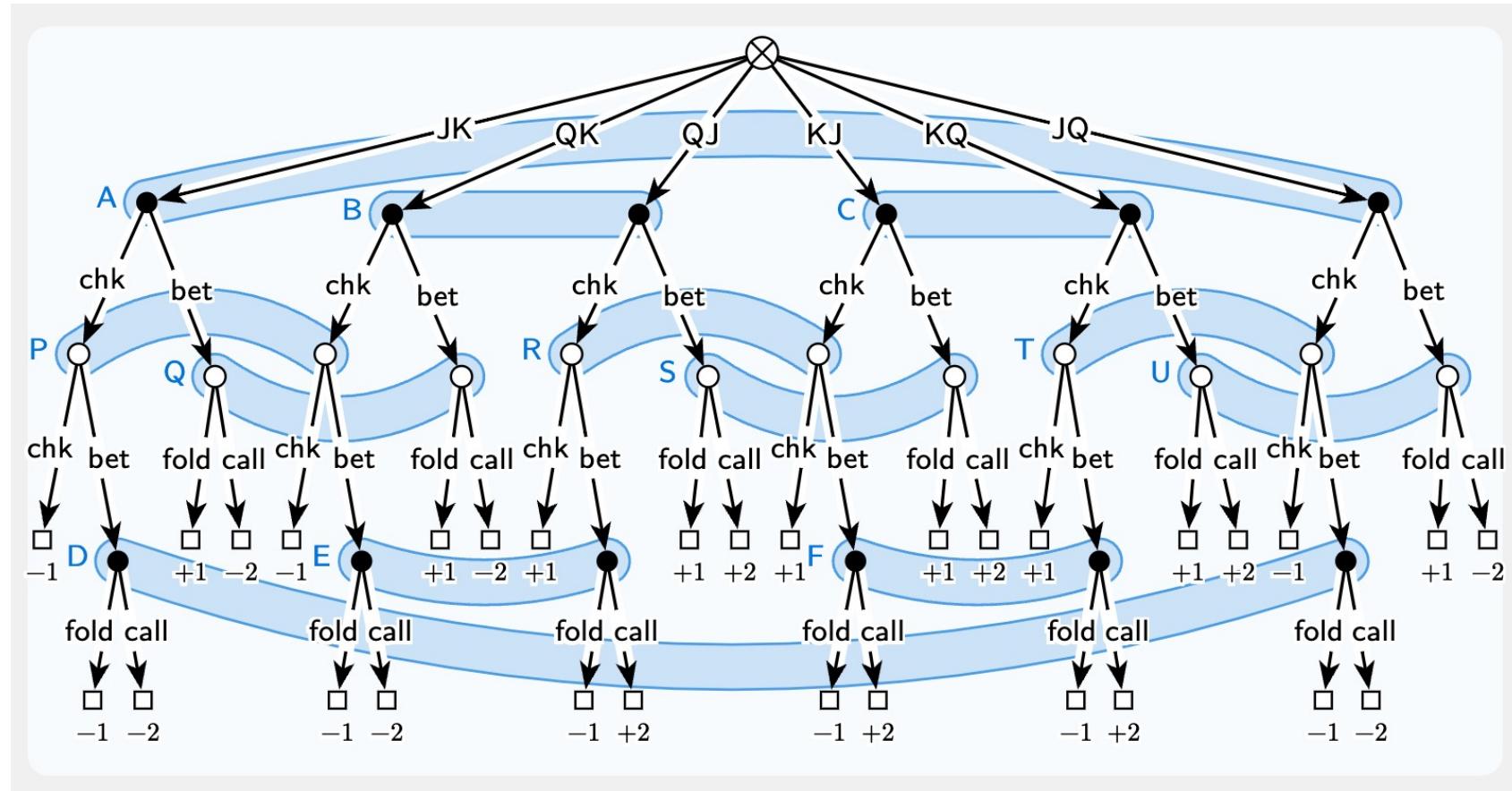


Decision Tree



Game Tree

# Plotting Decisions with Hidden Information: Game Tree vs Tree Form Decision Process



Extensive-form Game

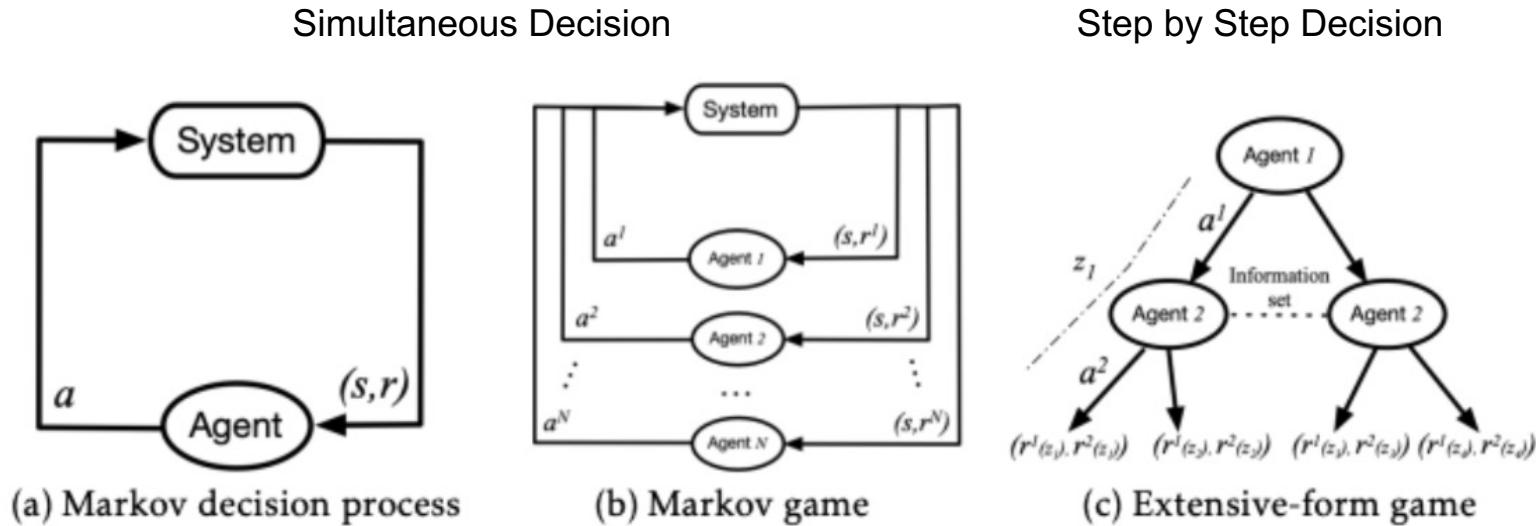
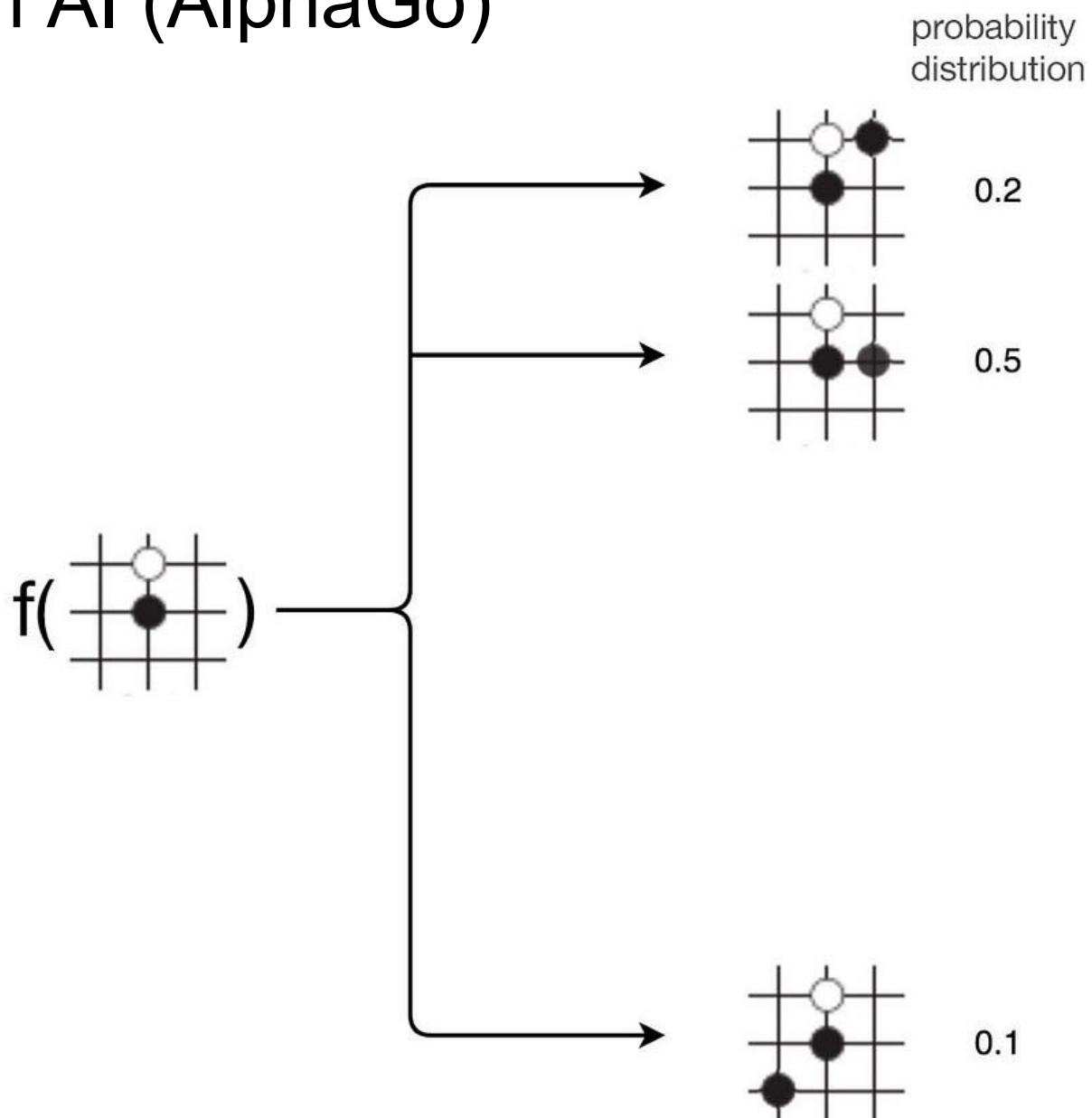
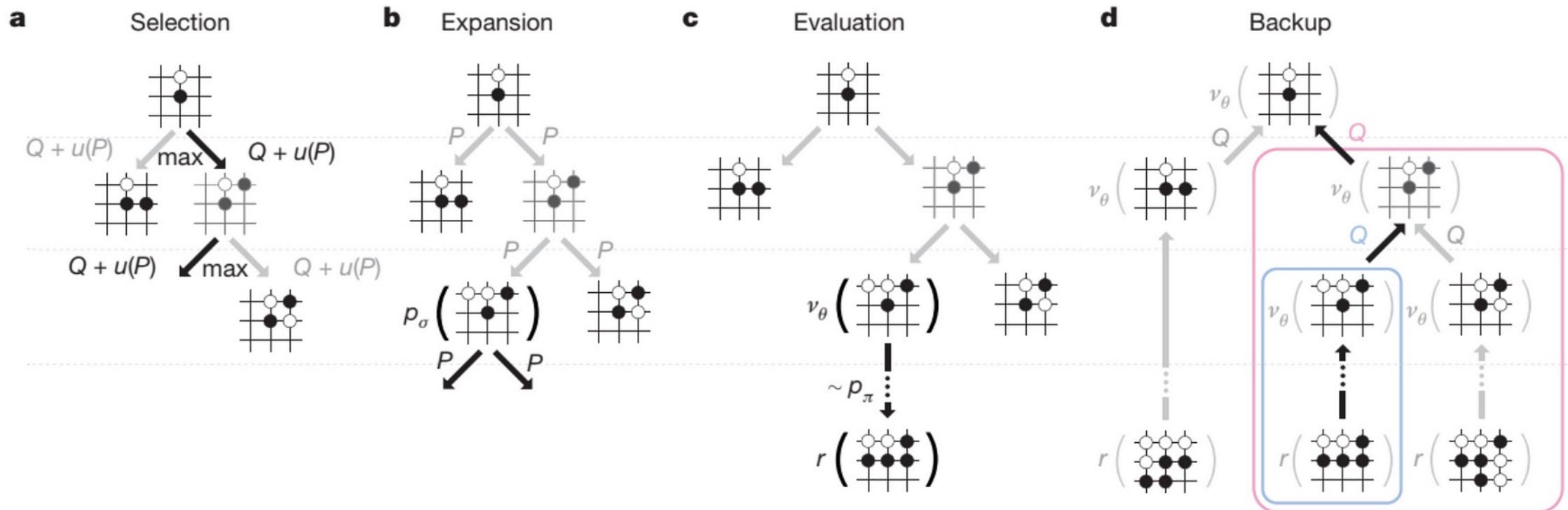


Figure 1: Schematic diagrams for the system evolution of a Markov decision process, a Markov game, and an extensive-form game, which correspond to the frameworks for single- and multi-agent RL, respectively. Specifically, in an MDP as in (a), the agent observes the state  $s$  and receives reward  $r$  from the system, after outputting the action  $a$ ; in an MG as in (b), all agents choose actions  $a^i$  simultaneously, after observing the system state  $s$  and receiving each individual reward  $r^i$ ; in a two-player extensive-form game as in (c), the agents make decisions on choosing actions  $a^i$  alternately, and receive each individual reward  $r^i(z)$  at the end of the game, with  $z$  being the terminal history. In the imperfect information case, player 2 is uncertain about where he/she is in the game, which makes the information set non-singleton.

# Modern Decision AI (AlphaGo)

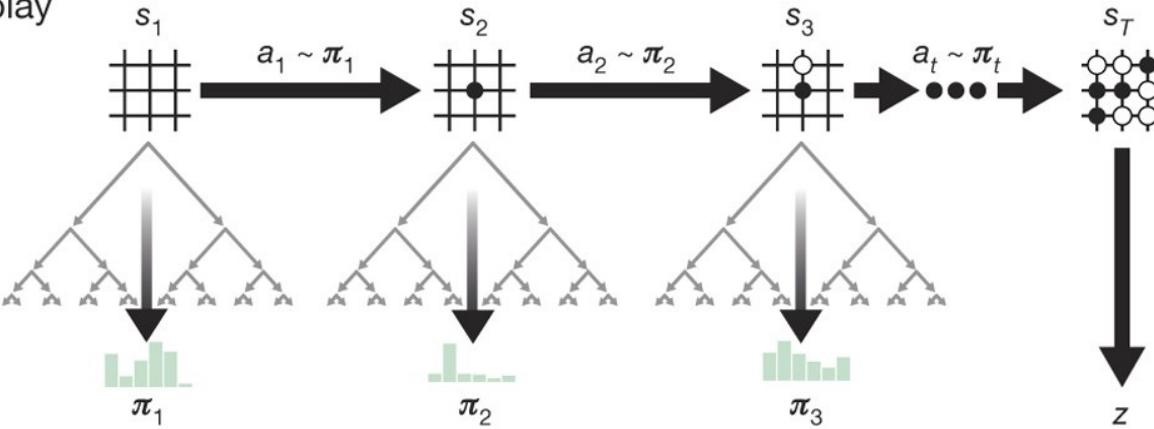


# Modern Decision AI (AlphaGo)

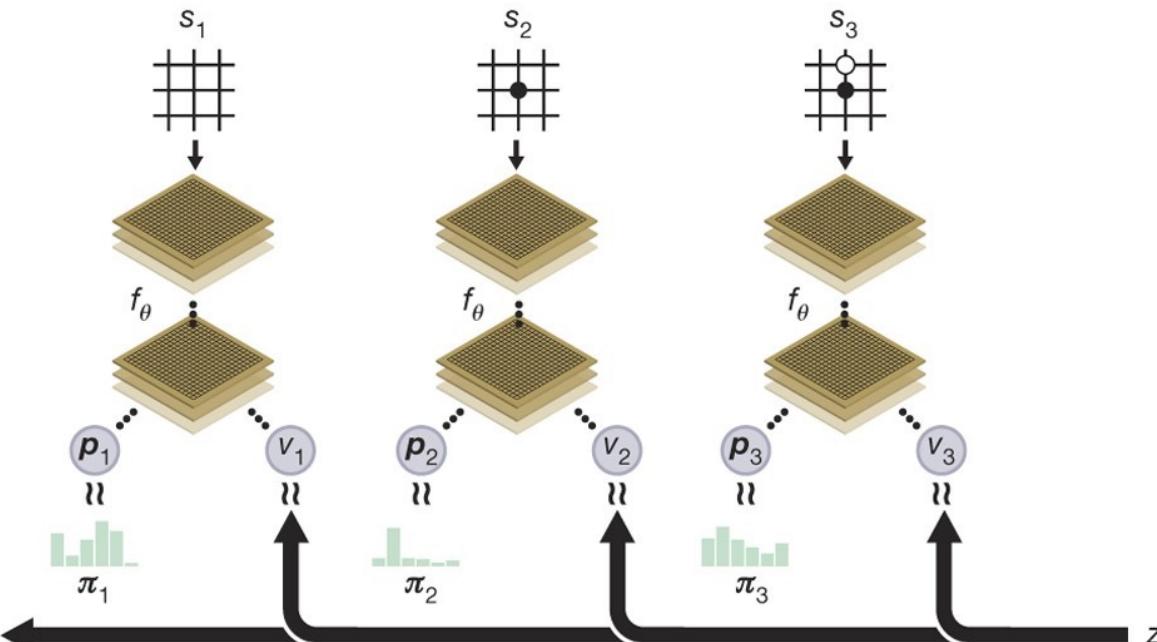


# Modern Decision AI (AlphaGo)

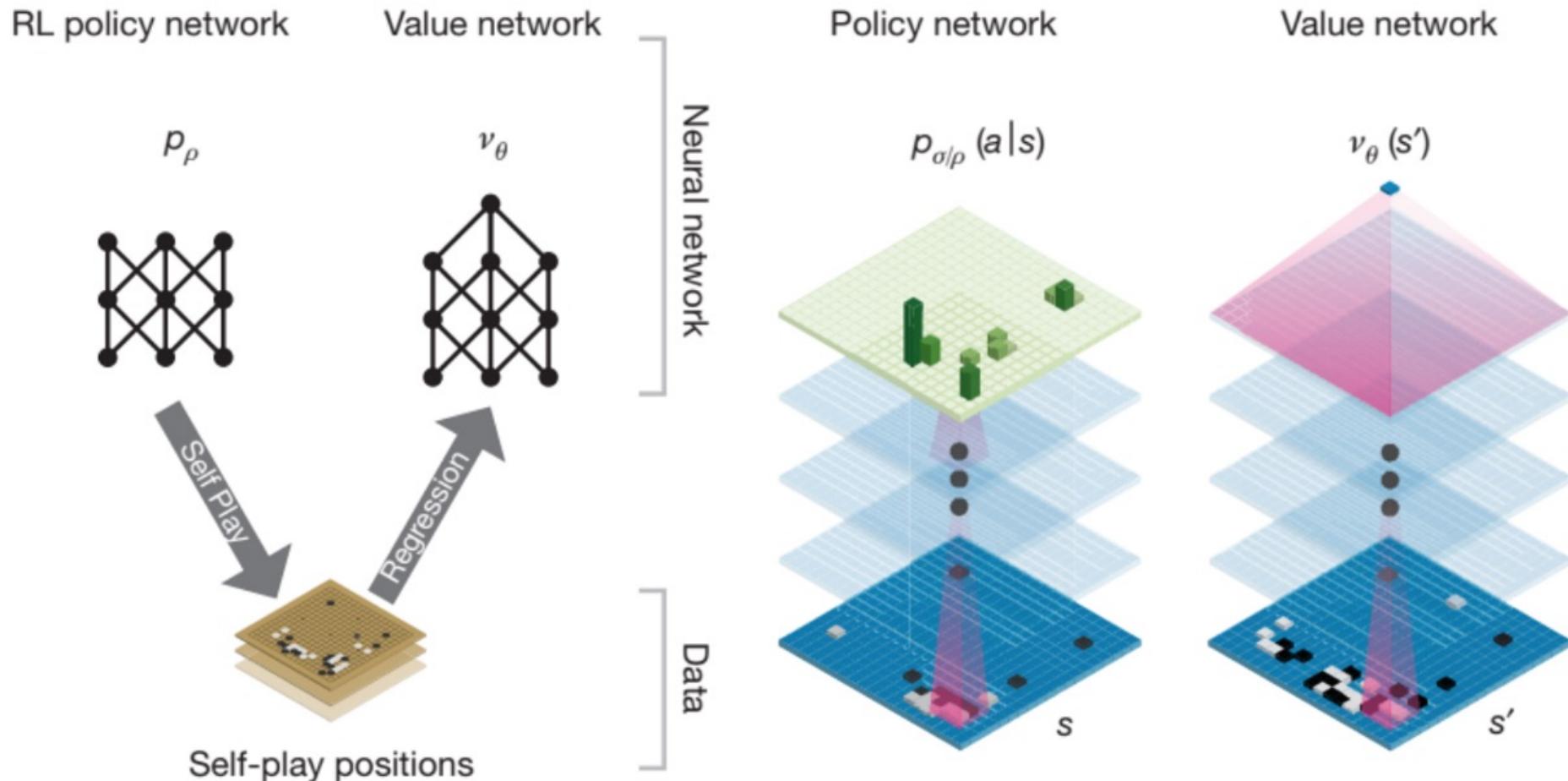
**a** Self-play



**b** Neural network training



# Modern Decision AI (AlphaGo)



# Decision-making between multiple players

Based on what we have, what else do we need?

# Decision-making between multiple players

Based on what we have, what else do we need?

Collaborator?

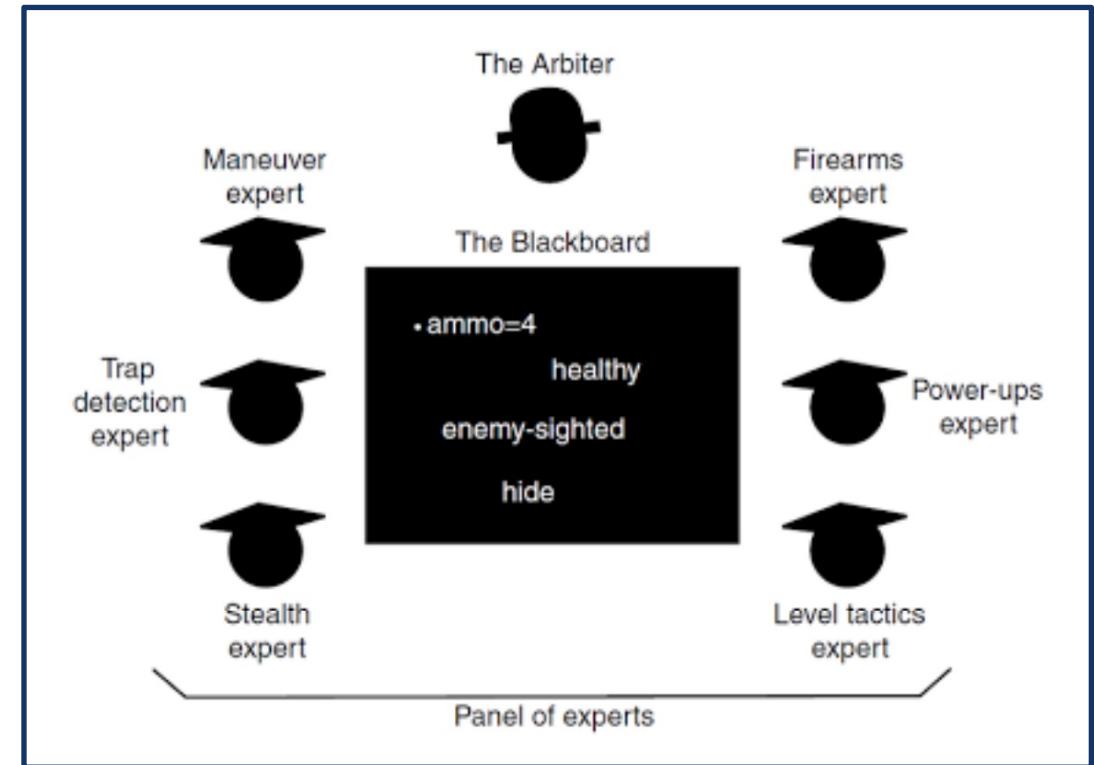
Roles? Teacher and students?

Shared Knowledge?

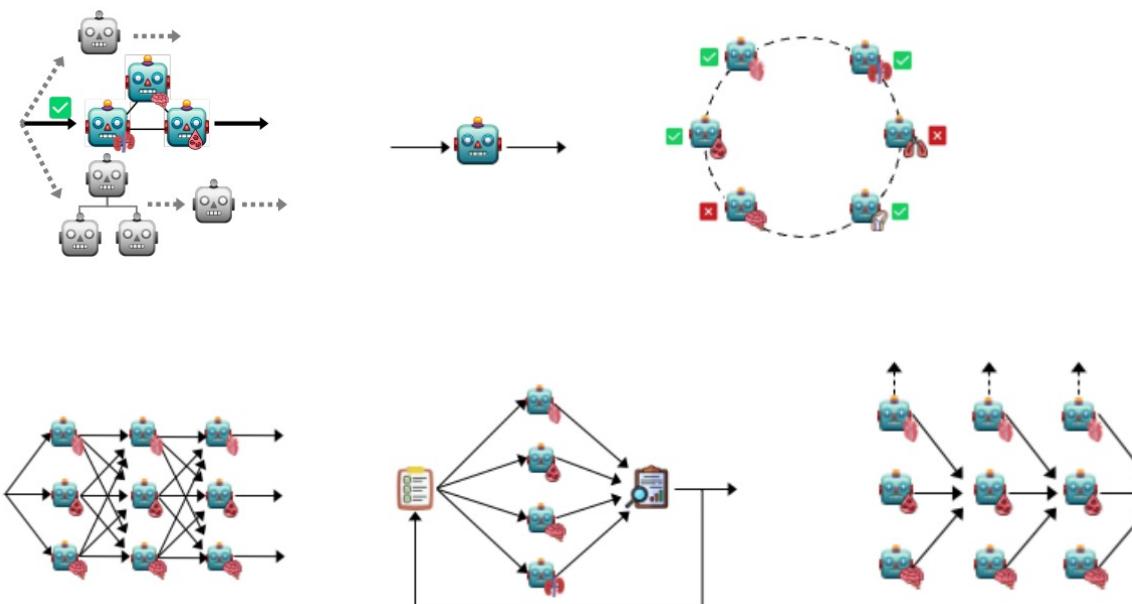
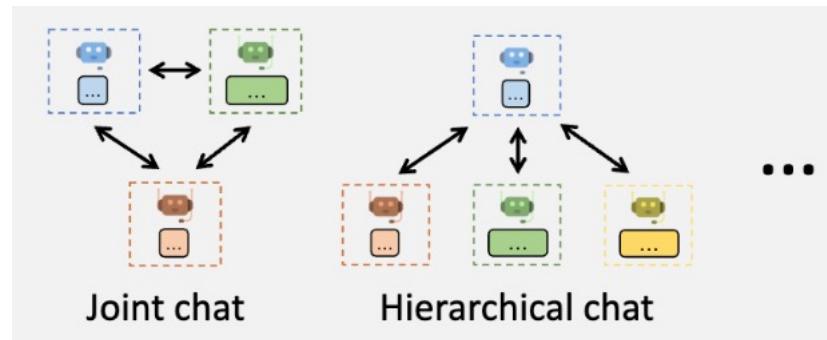
Supervisor?

Policy and rules?

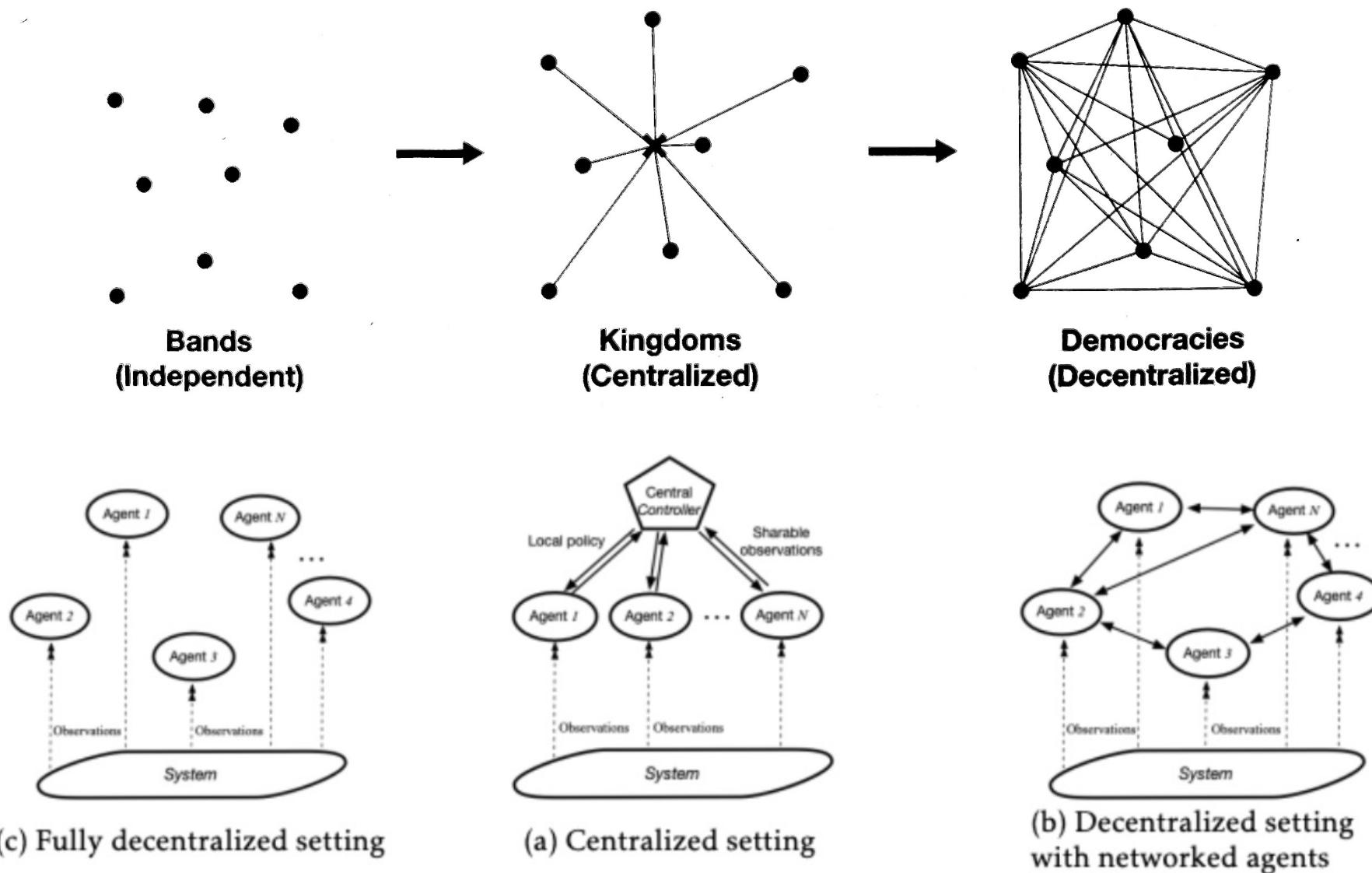
# Collaboration between multiple players - Blackboard Model



# Collaboration between multiple players - architectures



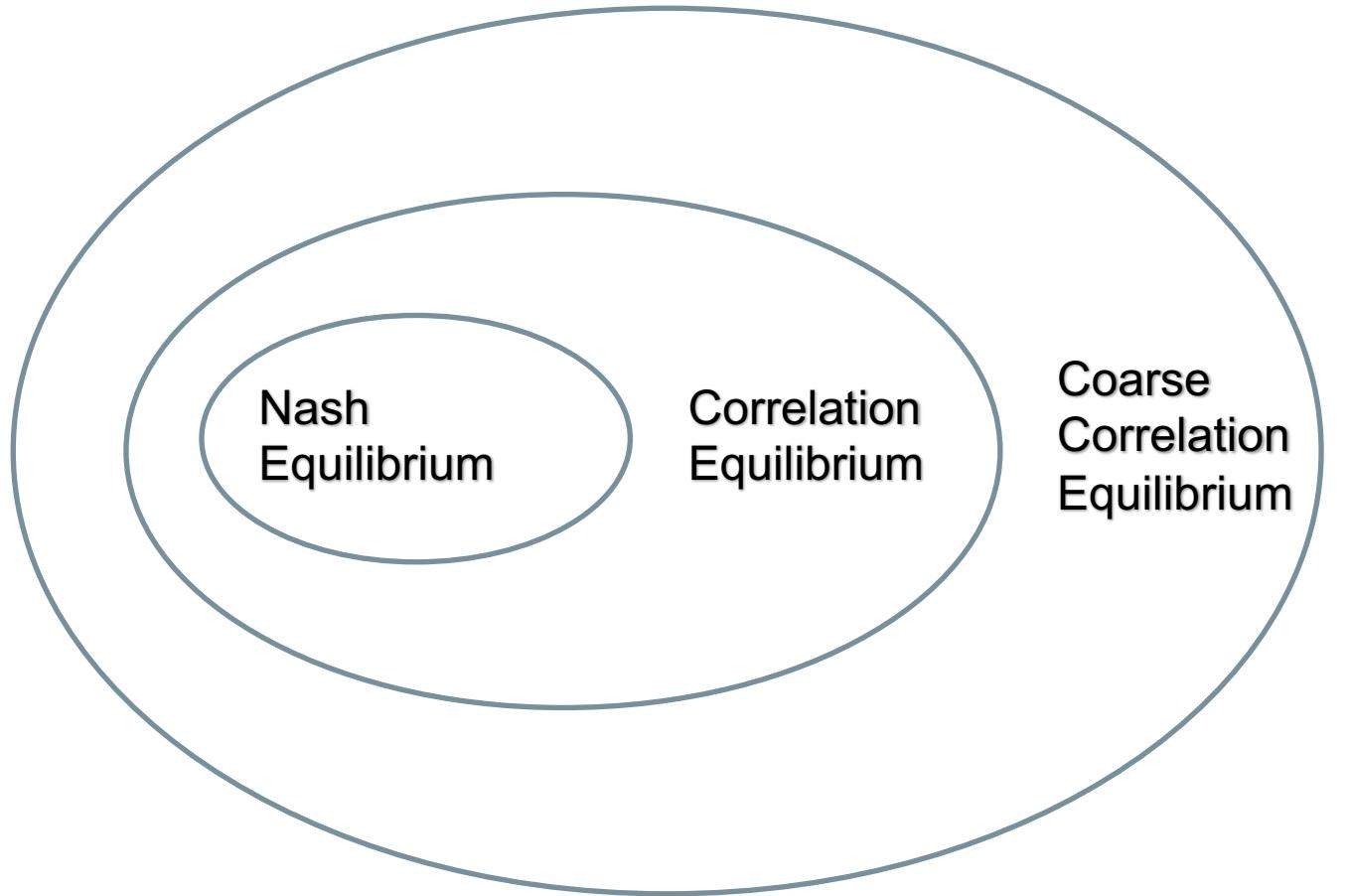
*The major ways human societies have been organized throughout history reveal a remarkably simple pattern that foreshadows how businesses are now changing.*



# Algorithms Inspired by Social Structures

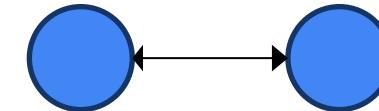
Category	Description	Illustrations	Algorithms
<b>Independent Learning</b>	Each agent learns independently, treating others as part of the environment.	Three separate circles, each labeled "Agent" below it, representing independent learning.	IQL, IPG, IA2C, ITRPO, IPPO
<b>Centralized Critic</b>	Uses a centralized critic to estimate value functions while policies remain decentralized for execution.	A central circle labeled "Central-critic" is connected to three separate circles labeled "Agent" by arrows, representing a centralized critic architecture.	COMA, MATRPO, MAPPO, MADDPG, MAA2C
<b>Value Decomposition</b>	Decomposes joint value functions into individual contributions to facilitate coordination among agents.	A group of four circles labeled "Joint Value" is connected by an arrow to three separate squares labeled "Individual contributions", representing value decomposition.	QMIX, VDN, QTRAN
<b>Regret-Based Methods</b>	Minimizing regret over iterations, commonly used in solving extensive-form games and multi-agent strategies.	Three circles inside an oval labeled "Min. Global Regret" with double-headed arrows between them, and a label "Min. Local Regret" below the oval, representing regret-based methods.	CFR, MC-CFR, MWU, Regret Matching, Regret Matching+

# Competition between multiple players – game theory 2.0 (Skip)

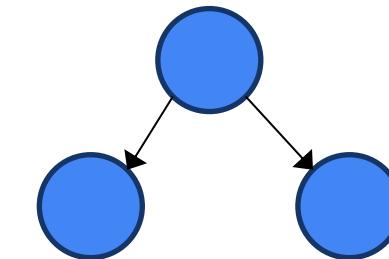


Easier to compute  
(converge) !

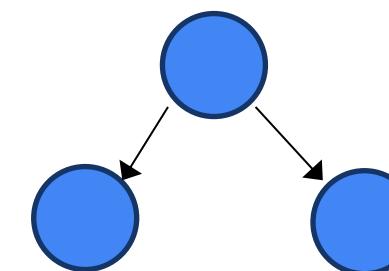
**NE:**



**CE:**



**CCE:**



# Why easier to compute (skip)

Maximize:

$$u + 2v + y$$

Subject to:

$$u + 2w \geq 3v + w$$

$$3y + z \geq x + 2z$$

$$2u + x \geq 3u - x$$

$$2u + x \geq u + 2x$$

$$3v - y \geq 2v + y$$

$$3v - y \geq v + 2y$$

$$w + 2z \geq 2w + z$$

$$w + 2z \geq 3w - z$$

$$u + v + w + x + y + z = 1$$

$$u, v, w, x, y, z \geq 0$$

CE can be expressed as  
linear programming problem

No need to go too deep,  
Think of:  
If we are going to design a new game,  
How can we design the collaboration and competition  
How can we design the shared/hidden information  
How can we design the actions?

+20 +19.5 129.4 +5.1 352 +7.6 TURN 121/500  
12/12 2/2 0 1 1 11:51AM 125AD ?



### WORLD TRACKER

#### ENGINEERING

Turn: 3 Build Ancient Walls

#### RECORDED HISTORY

Turn: 6 Build 2 Campus districts

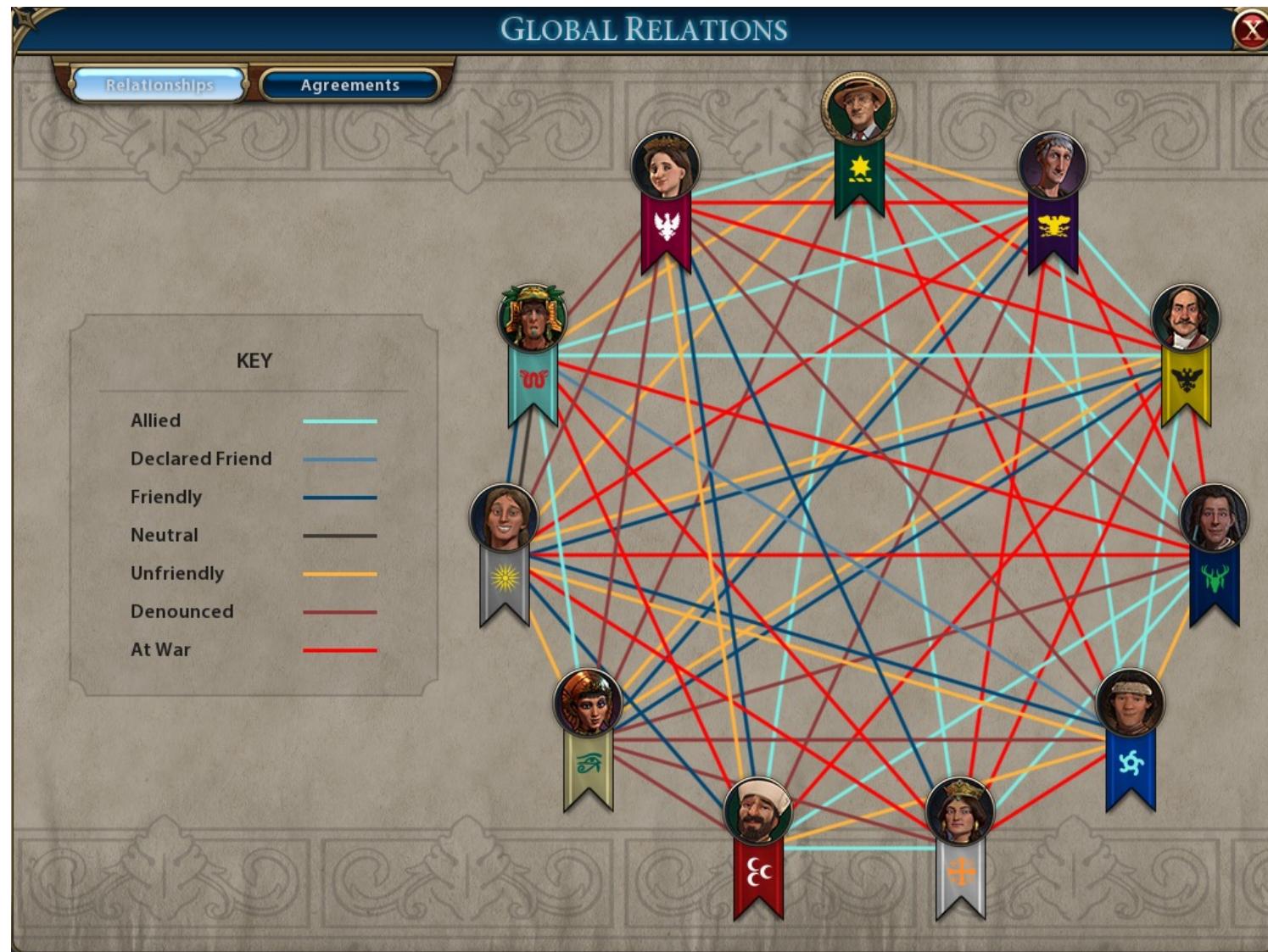


**EUROGAMER**

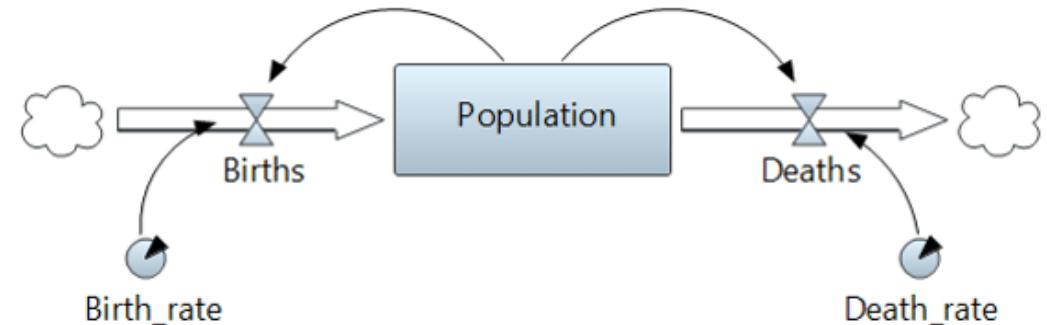
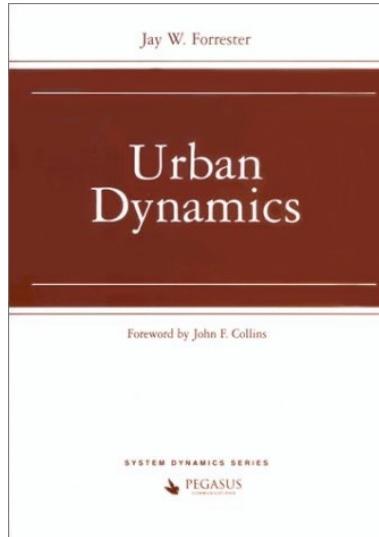
Since the game has entered a new era, you are able to make a Dedication to guide your people towards the desired future for your civilization.

## Example: Civilization Relation System Design

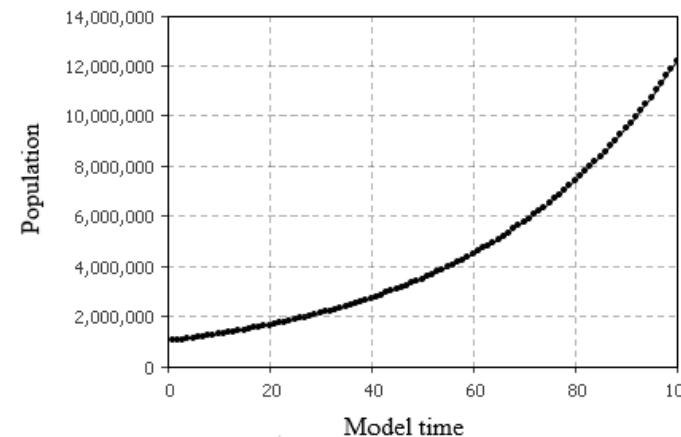
State
Ally
Declared Friend
Friendly
Neutral
Unfriendly
Denounced
At War



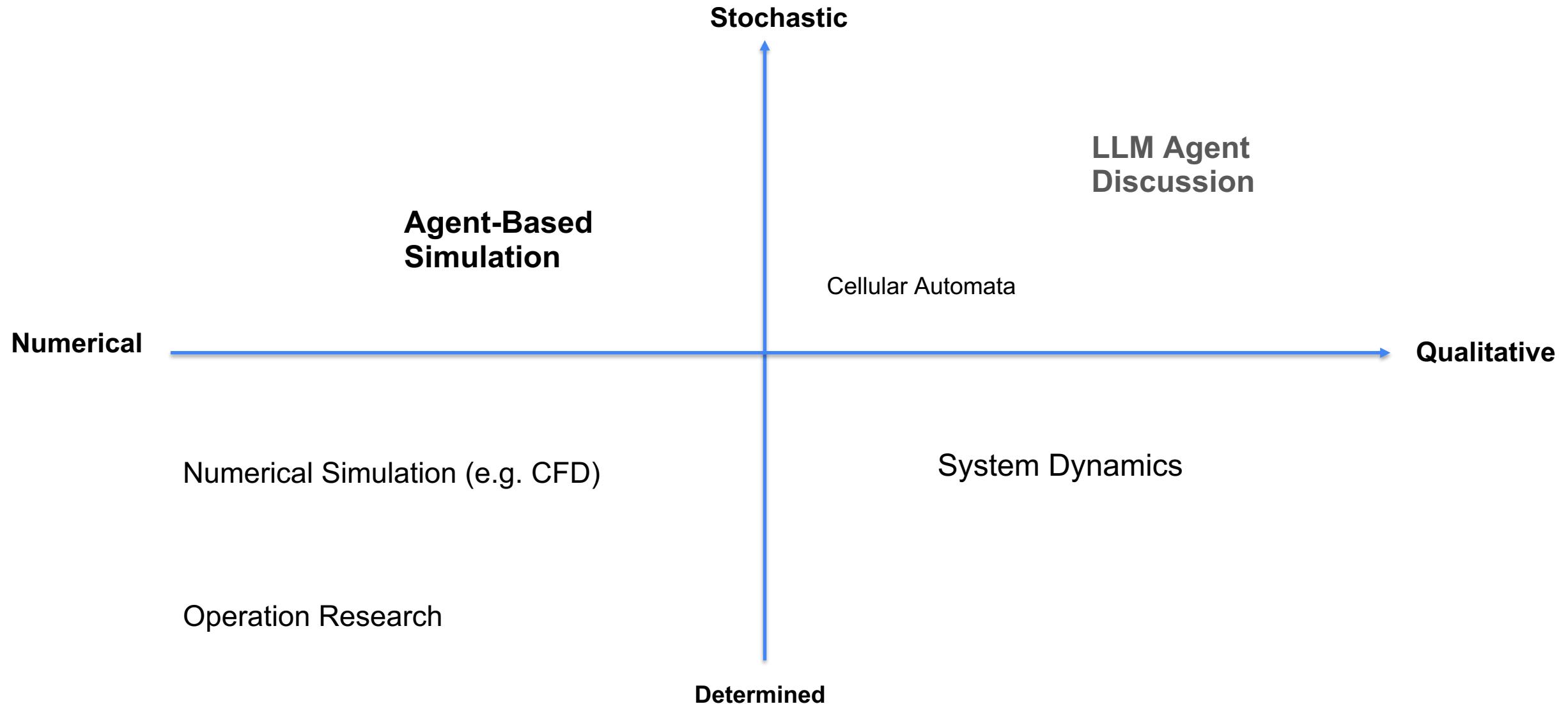
# Next Class: Macro-scale: System Dynamics



Introduce System Dynamic Model to Simulate:  
Population Change  
Economical Cycles  
...



# Simulation Methodologies and their Relationships



# Workshop

- Group formation, mockups, playtesting, and refinement of your conceptual board game.
- Free food will be provided to celebrate my birthday!