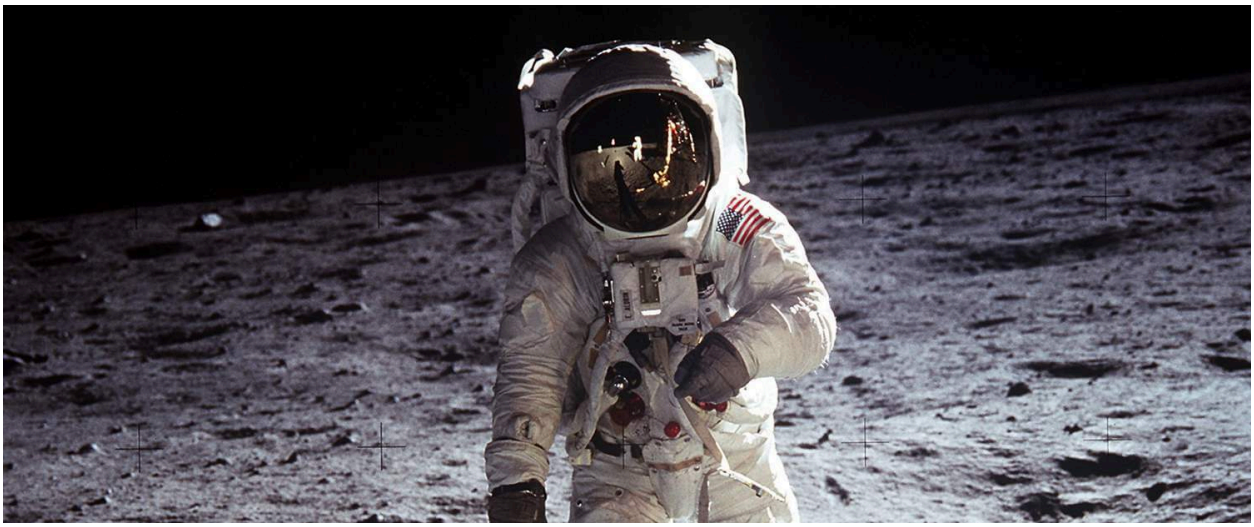

Civilization Diplomacy v2.0

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This document aims to explain civilization diplomacy simulation logic in detail and propose a hypothesis we want to evaluate.

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1. Introduction

This simulation represents the development and interactions of several civilizations over several planets in a common space setting. Each civilization has military strength, culture, technology, population, economy, and resource assets. The main objective is to exhibit how those factors affect:

- Population growth and economic development,
- Trade and resource exchange,
- Diplomatic relationships,
- Conflict initiation and resolution,
- Technological and cultural evolution.

The simulation examines emerging behaviors generated through these dynamics and explores parameters and conditions under which civilizations thrive, cooperate, or go to war.

Definitions

Symbol	Meaning	Example
f_c	Food consumption per capita	1 unit per 1000 people
e_c	Energy consumption per capita	1 unit per 10000 people
α_T	Energy per unit tech	0.1
α_M	Energy per unit military	0.1
m_c	Minerals per military unit	0.3
β_P	Tech growth scaling by population	0.5
β_E	Tech growth scaling by energy	0.3
θ	Aggressiveness after victory multiplier	0.15

β_f	Cultural pacification rate	0.1
ϵ_r	Weight for the resource pressure	0.5
ϵ_p	Weight for the population pressure	0.5
Resource interval	The minimum and maximum possible resource values	[100, 500]
Population cap interval	The minimum and maximum possible population cap values	[1000, 3000]

2. Core Components and Variables

2.1 Starting resources

Each **planet** will have the following resources:

- S_p **: Planet size** - cap of the population, fixed cap
- M_p **: Minerals** - resource critical for military
- E_p **: Energy** - boosts military and tech
- F_p **: Food** - boost population, availability decreases as population increases.

Each **civilization** will have the following resources:

- T_i **: Tech** - boosts over time with population growth and gets an additional boost if energy is present
- W_i **: Military** - represents a percentage of the population + military boost which is tech + minerals
- P_i **: Population** - starting is 1000 people
- $R_i = (M_i, F_i, E_i)$ **: Resources** - a tuple of resources that are available to this civilization based on which planets they control.
  Example:
  `resources = ['Energy': 10, 'Food': 15, ...]`

- C_i **: Culture** - an abstract resource that represents how developed civilization is. Consists of population + tech + resources, when culture reaches maximum, civilization wins
- Fr_i **: Friendliness** - an abstract value that represents how likely this civilization is to attack another civilization, the more victories a civilization has, the less its friendliness, assigned randomly
- V_i : **Victories** - the number of victories civilization has (default is 0)
- D_i : **Desperation score** - Calculated based on population pressure and resource pressure
- $Diplomacy_i$: **Diplomacy**, stores values `['12' : 1, '2' : 0]` which mean that civilization 12 is at war with civilization i and civilization 2 is at peace. Default values are all 0. (All at peace).

2.1 Population and Growth

Population *P* represents the labor force and production capacity.

$$P_i(t+1) = P_i(t) + g_i(t) \cdot P_i(t)$$

Where $g_i(t)$ is a growth rate determined by:

$$g_i(t) = g_{max} \cdot min(1, \frac{F_i(t)/P_i(t)}{f_c})$$

$$g_{max} = 0.01 + 0.0005 * tahn(\frac{T_i}{100})$$

If food per capita is insufficient, growth slows proportionally.

2.2 Economy and Resources

- Food demand:

$$d_iF(t) = f_c \cdot P_i(t)$$

- Energy demand:

$$d_e E(t) = e_c \cdot P_i(t) + \alpha_T \cdot T_i(t) + \alpha_M \cdot M_i(t)$$

- Minerals demand:

$$d_i W(t) = m_c \cdot M_i(t)$$

2.3 Technology

Technology evolves based on population-driven innovation and energy investment:

$$T_i(t+1) = T_i(t) + \beta_P \cdot log(P_i(t)) + \beta_E \cdot \frac{E_i(t)}{P_i(t)}$$

2.4 Culture

Culture integrates population, technology, and resources:

$$C_i(t) = \delta_P \cdot P_i(t) + \delta_T \cdot T_i(t) + \delta_R \cdot R_i(t)$$

2.5 Military

Military strength combines population, technology, and minerals:

$$W_i(t) = \sigma_P \cdot P_i(t) + \sigma_T \cdot T_i(i) + \sigma_M \cdot R_i^M(t)$$

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3. Interactions

3.1 Trade Relations

Trade exchanges surplus resources for scarce ones:

- Surplus and deficit defined as:
  - $surplus_{i,k} = max(0, r_{i,k} - d_{i,k})$,
  - $deficit_{i,k} = max(0, d_{i,k} - r_{i,k})$
    - Where $d_{i,k}$ is a demand of civilization i for the resource k
    - Where $r_{i,k}$ are current holdings (both controlled + imported)

Per-turn logic:

For each civilization C_i

1. Calculate `demand` and `surplus` for each resource type
2. For each resource *k* where $deficit_{i,k} > 0$:
    a. Search for the closet civilization with
        i. $surplus_{i,k} > 0$
        ii. Is in range to trade with C_i
    b. Rank candidates as:
        i. All C_j that are NOT at war with C_i
        ii. Proximity (closer the better)
        iii. Cultural similarity as $sim_{i,j} = 1 - \frac{|C_i - C_j|}{max(C_i, C_j)}$
        iv. Friendliness
        v. Mutual needs (if C_j also needs something from C_i)
    c. Select the best partner C_j
    d. Establish trade deal:
        i. Amount: $min(deficit_{i,k}, surplus_{i,k})$
        ii. If there is a *mutual need,* do same for the deficit resource
        iii. If there is **no** mutual need, C_j gets boost tech
3. Execute the deal (update resources and tech)

3.2 Conflict

War probability

War is a probabilistic even which is decided by various factors.

Overall formula is:

$$WarScore_{i,j} = w_1 \cdot (1 - F_i) + w_2 \cdot Pp_i + w_3 \cdot Rp_i + w_4 \cdot \triangle C_{i,j}$$

Where w_1, w_2, w_3, w_4 are weights with values: 0.3, 0.3, 0.2, 0.2 respectively.

1. F_i - friendliness of the attacking civilization
2. $Pp_i = max(0, \frac{P_i - Cap_i}{Cap_i})$ - Population pressure
3. $Rp_i = \frac{\sum_k Deficit_{i,k}}{\sum_k Demand_{i,k}}$ - Resource pressure
4. $\triangle C_{i,j} = \frac{|C_i - C_j|}{max(C_i, C_j)}$ - Cultural differences

Friendliness

at t = 0: $F_i(0) = Uniform[0, 1]$

other t:

$$F_i(t+1) = max(0, F_i(t) - \theta \cdot V_i(t))$$

where $V_i(t)$ is the number of victories by the civilization at that time.

Cultural smoothing effect

$$F_i(t+1) = F_i(t) + \beta_f \cdot (\frac{C_i(t)}{C_{max}})$$

Where β_f is a cultural pacification rate

3.3 War

War, once declared, doesn't end until one civilization or the other seizes to exist.

Per-turn logic:

For each civilization C_i we check all civilization it can reach C_j and:

1. Calculate the $WarScore_{i,j}$
2. If the $WarScore_{i,j}$ > `random.random()` then C_i declares war on civilization C_j,
    a. invades ALL planets they can reach that C_j controls:
        i. if $W_i > W_j$ then C_i wins (same way if <)

ii. if C_i (attacker) wins:

1. C_i gains control of planet P it invaded. C_j looses planet P which means:
   a. C_i gets all the resources planet P has. C_j looses them
   b. C_i looses from 5 to 10% of the population due to war, C_j looses from 5 to 10% of population due to war
   c. C_i gains from 50 to 60% of the CAP population of planet P, C_j looses THAT amount
2. V_i increments by 1 (victory) which influences friendliness

3. If C_j (defender) wins:
   a. C_j looses from 3 to 7% of their population due to war
   b. C_i looses from 5 to 10% of their population due to war (since they are the aggressor)
   c. C_j gets to keep the planet
   d. V_j increments by 1 (victory) which influences friendliness

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4. Turn logic

1. At the beginning of each turn for each civilization C_i do:
   a. Calculate all their properties for this turn `t`
   b. If C_i is considered desperate (D_i > 0.6) then it first searches for war opportunities (As per **3.3**) $D_i = \epsilon_p \cdot Pp_i + \epsilon_r \cdot Rp_i$
      i. War happens, civilizations' involved properties are recalculated
      ii. Trade happens with those C_j that C_i is not in war with
   c. Else, civilization will look for trade opportunities first.
      i. Trade happens, civilizations' involved properties are recalculated
      ii. C_i proceeds to attack those C_j that it is in war with

2. At the end of turn, check for culture victory and for the military victory

Modeling scenarios

We have decided to construct following scenarios:

- Friendzone
  - Everyone is friendly at the beginning of the game
- Thunderdome
  - Everyone is unfriendly at the beginning of the game
- Juggernaunt
  - One civilization gets excess of resources and is unfriendly
- Wolf
  - Where everyone is friendly, one civilization is unfriendly

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5. Hypotheses

- **H1:** Rapid tech growth accelerates military power, increasing war initiation risk.
- **H2:** Economic desperation increases war probability to acquire resources.
- **H3:** Population pressure acts as a catalyst for conflict when civilizations cannot expand territorially.
- **H4:** Cultural similarity promotes diplomacy and trade, reducing conflicts.
- **H5:** Civilizations with higher initial friendliness and cultural development are more likely to establish enduring trade networks, leading to long-term stability and growth.
- **H6:** Repeated victories decrease friendliness and increase aggressiveness, potentially triggering a cycle of escalating conflicts that can destabilize even well-resourced civilizations.

6. User guide (duplicated from readme.md)

1. Unpack zip into an empty folder

2. After unpacking, make sure you have installed: `numpy, json, re, myplotlib, unittest, random, collections, pandas, ast, os, time, seaborn, shutil`
3. Then open terminal and run `python3 init.py` or `python init.py`
4. Follow the UI.
    a. In case errors "folder output not found" or "folder logs not found" or "folder plots" not found
    b. Create folder output/ and logs/ and plot/ INSIDE the output/ folder as :

5. 5. Enjoy! :)

P.S. Visualization is saved as .gif

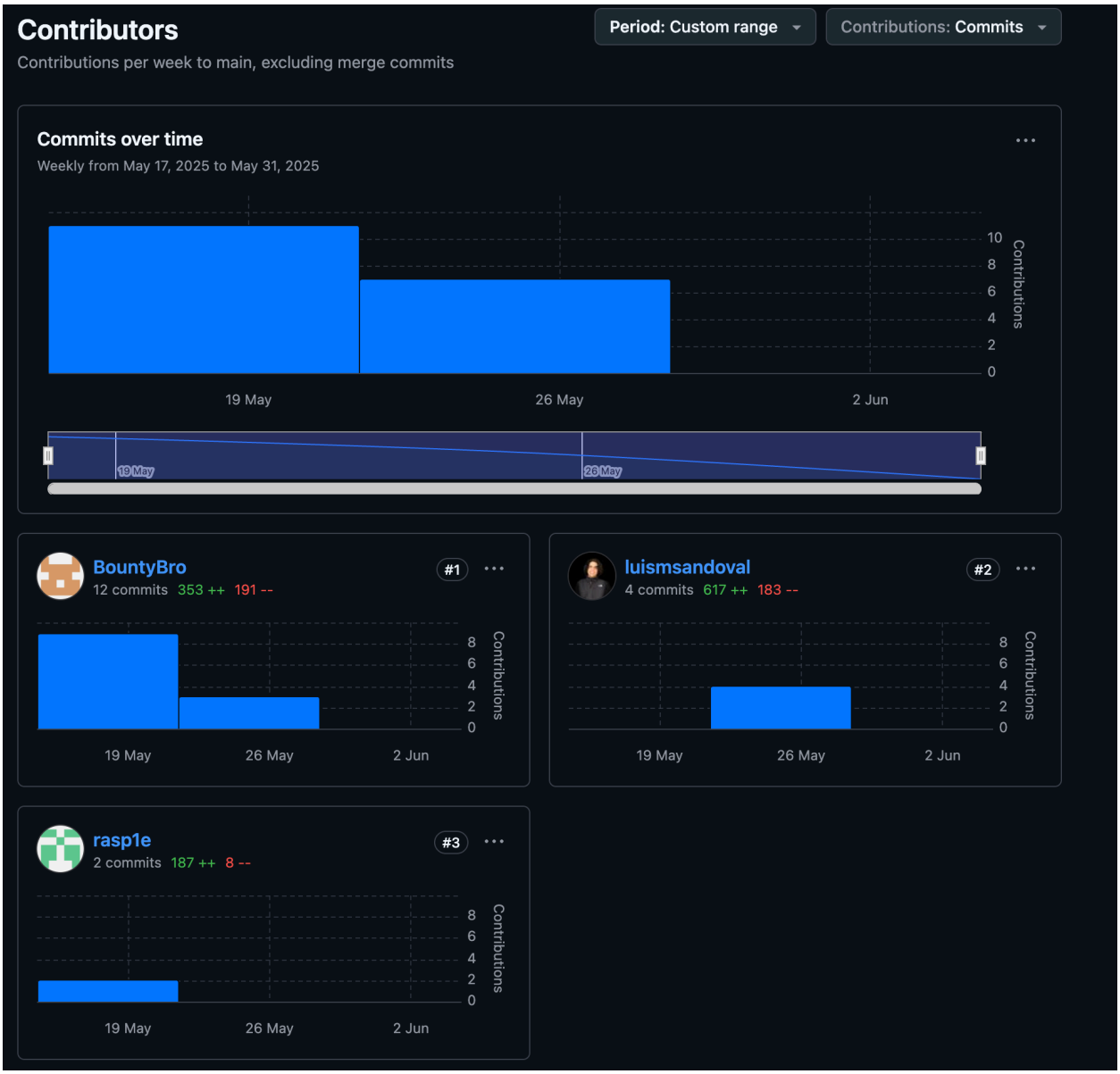
7. Team Work

We believe, everyone had worked equally during this project and committed their time and resources equally. Zones of responsibility:

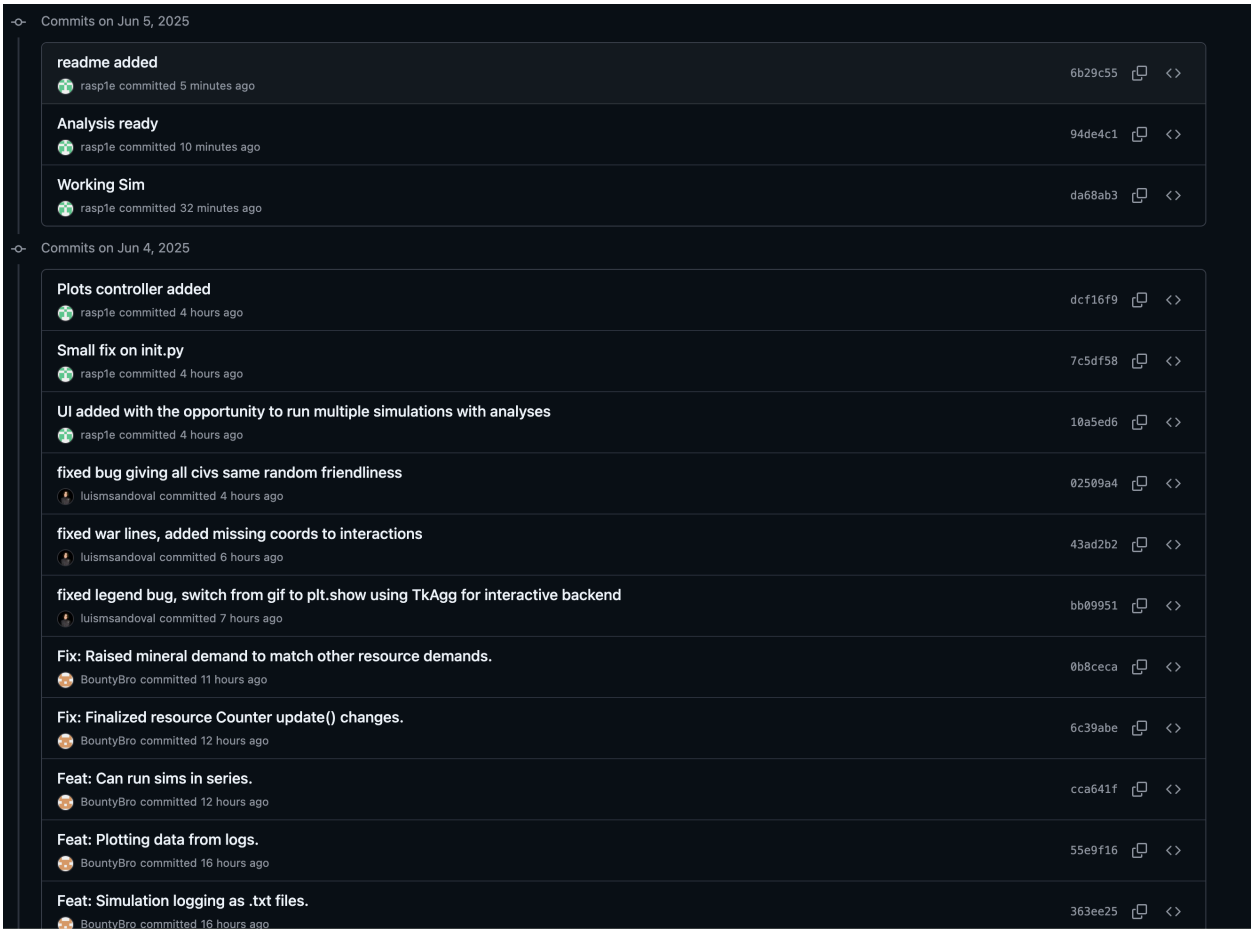
- Daniil Marozau: Overall idea, documentation, presentation, initial setup, UI, analyses.
- Noah Brestel: Implementation: simulation logic, bug fixing, idea corrections, agent implementation.
- Luis Sandoval: Implementation: visualization, bug fixing, idea corrections, agent modification, analyses visualization

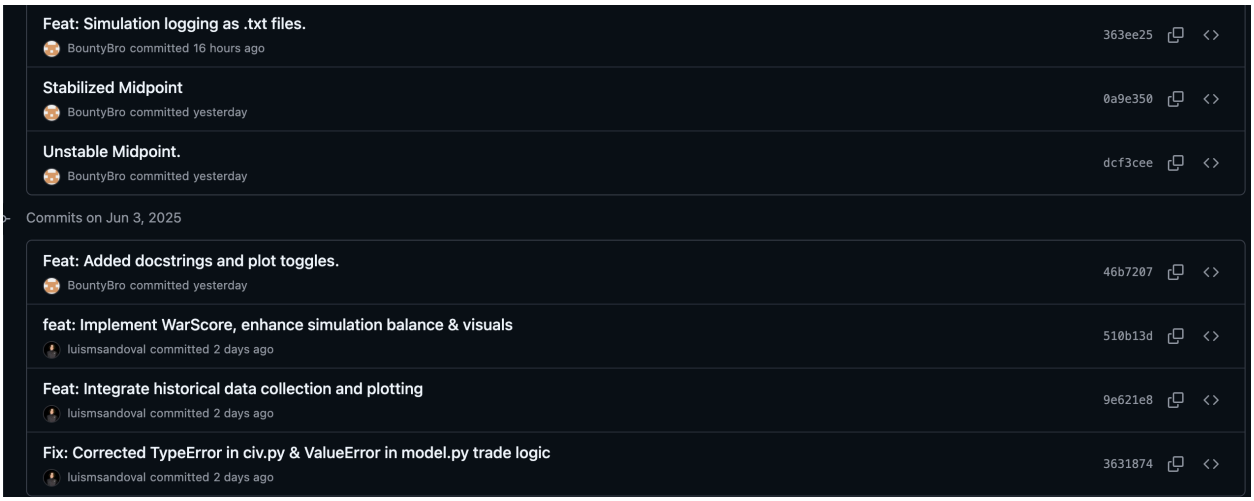
Commit history:

Up unitl June 2nd:



June 2nd - June 5th:


Commits on Jun 5, 2025
readme added
rasp1e committed 5 minutes ago
6b29c55
Analysis ready
rasp1e committed 10 minutes ago
94de4c1
Working Sim
rasp1e committed 32 minutes ago
da68ab3
Commits on Jun 4, 2025
Plots controller added
rasp1e committed 4 hours ago
dcf16f9
Small fix on init.py
rasp1e committed 4 hours ago
7c5df58
UI added with the opportunity to run multiple simulations with analyses
rasp1e committed 4 hours ago
10a5ed6
fixed bug giving all civs same random friendliness
luismsandoval committed 4 hours ago
02509a4
fixed war lines, added missing coords to interactions
luismsandoval committed 6 hours ago
43ad2b2
fixed legend bug, switch from gif to plt.show using TkAgg for interactive backend
luismsandoval committed 7 hours ago
bb09951
Fix: Raised mineral demand to match other resource demands.
BountyBro committed 11 hours ago
0b8ceca
Fix: Finalized resource Counter update() changes.
BountyBro committed 12 hours ago
6c39abe
Feat: Can run sims in series.
BountyBro committed 12 hours ago
cca641f
Feat: Plotting data from logs.
BountyBro committed 16 hours ago
55e9f16
Feat: Simulation logging as .txt files.
BountyBro committed 16 hours ago
363ee25


Feat: Simulation logging as .txt files.
BountyBro committed 16 hours ago
363ee25
Stabilized Midpoint
BountyBro committed yesterday
0a9e350
Unstable Midpoint.
BountyBro committed yesterday
dcf3cee
Commits on Jun 3, 2025
Feat: Added docstrings and plot toggles.
BountyBro committed yesterday
46b7207
feat: Implement WarScore, enhance simulation balance & visuals
luismsandoval committed 2 days ago
510b13d
Feat: Integrate historical data collection and plotting
luismsandoval committed 2 days ago
9e621e8
Fix: Corrected TypeError in civ.py & ValueError in model.py trade logic
luismsandoval committed 2 days ago
3631874