HPS

Kimia Taba and Vincent Hasse

Predator-Prey Relationship in a Closed System

Table of contents

The Idea

create a simulated environment

plants, prey, hunters

apply some machine-learning for prey- and hunter-brains -> Python

Outline

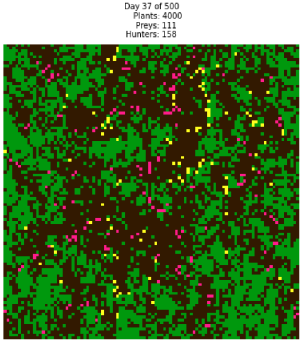
World: NumPy-Array, int8

- 0: Free
- 1: Plant
- 2: Prey
- 3: Hunter
- ... 255 different agents possible
- initialized randomly at the beginning of the simulation, based on config-file

Agents: Prey and Hunters

- can move, eat, breed, die

Plants: are just dead or alive, spawn randomly every simulation-step



Pseudo-Code

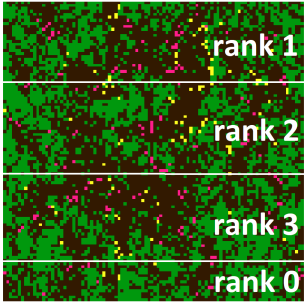
`Sequential-Simulation` in Pseudo-Python

pseudo-python

```
for step in range(config.SIMUALTION_STEPS):
    for everyAgent in dicts:
        addAge()
        moveAgent()
            letItDie(energy, age)
            letItEat(isFoodAtNewPosition)
            letItBreed(energy)
    spawnNewPlants()
```

based on a dict of hunters and a dict of preys: (ID -> Animal)

General Idea for the Parallel Approach



Split the world in (even) chunks

Broadcast world state and Hunter / Prey dicts to every process

Each process calculates changes in the respective part of the world

Report changes to rank0

Rank0 gathers changes, creates new world and dicts and broadcasts for next simulation step

Problems and Solutions

Problem: Pickeling & sending of Hunter/ Prey dictionaries is costly

Solution: don't broadcast the dicts

- Change dicts from (AnimalID -> Animal) to (position -> Animal)
- Report back a numpy array with old Positions (as identifier), new Positions
- –> Broadcast world-state from rank0
- –> Send changes-array back to rank 0
- Only communicate NumPy Arrays

Drawback: rank0 has to do all the updating (world, dicts)

Parrallel movement calculation

Movement-Calculation in Python; first part

```python
#create lists
hunters = []
preys = []
#loop dependent on rank
for x in range((rank-1)*numRows, rank*numRows):
    for y in range(config.WORLD_SIZE):
        if world[x][y] == config.IDENT_PREY:
            preys.append((x,y))
        elif world[x][y] == config.IDENT_HUNTER:
            hunters.append((x,y))

#numslice: number of possible agents in slice +1
changes = np.zeros((numSlice, 4), dtype=changes_dtype)
changeCounter = 0
```

Parrallel movement calculation

Movement-Calculation in Python; second part

```
for p in preys:
    #loop through list and calculate new position
    path = helper.calculateSteps(p, world, config.IDENT_PLANT)
    if path != None:
        changeCounter += 1
        newPos = (path[1][0], path[1][1])
        changes[changeCounter][0] = p[0]    #save old...
        changes[changeCounter][1] = p[1]
        changes[changeCounter][2] = newPos[0] #and new position in array
        changes[changeCounter][3] = newPos[1]
#do the same for hunters
#update function only needs to run on the part of the array that...
changes[0][0] = changeCounter           #...actually contains changes
comm.Send(changes, dest=0)
```

Problems and Solutions

Problem: Rank0 has to apply all calculated changes

(Partial) Solution: Already apply changes of fastest process while waiting for callback of the other ranks

rank0 Receive

```
1  if rank == 0:
2      #process changes from other ranks
3      while received_data < numReceives:
4          changes = np.zeros(**_in respective size_**)
5          #wait for fastest callback
6          comm.Recv(changes, source=MPI.ANY_SOURCE, status=status)
7          #apply changes from data to world
8          world = sWorld.updateWorld(changes)
9          received_data += 1
10     sWorld.finishStep()
```

Problems and Solutions

Problem: When the world gets larger, also the broadcasted arrays (world, changes) get larger

Solution: No solution, it's implicit to the implementation :(

–> performance limits?

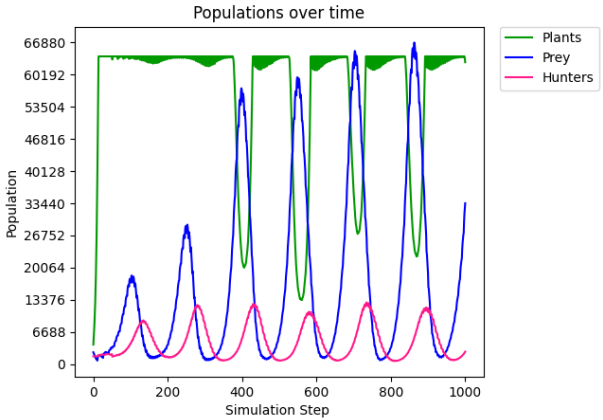
However: keep the memory size of communicated arrays as small as possible:

rank0 Receive

```
1  # smallest possible datatype for changes array (can be further optimized)
2  if config.WORLD_SIZE * numRows > 255:
3      changes_dtype = np.uint16
4      if config.WORLD_SIZE * numRows > 65535:
5          changes_dtype = np.uint32
6          if config.WORLD_SIZE * numRows > 4294967295:
7              changes_dtype = np.uint64
8  else: changes_dtype = np.uint8
9  #world:10.000 x 10.000; uint8 ~ 95,4MB;  changes with n = 50; uint ~7,6MB
```

Does it work

Yes. Populations are as to expect according to the Lotka-Volterra Laws:



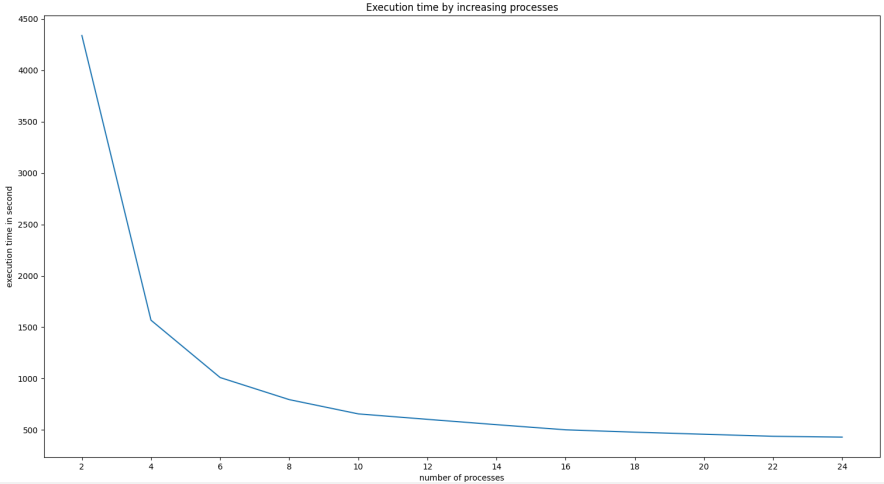
Base Config

World Size=1000, Simulation Steps=100

Without Paralleling => World Size = 500 , 10 simulation steps => 47 minutes

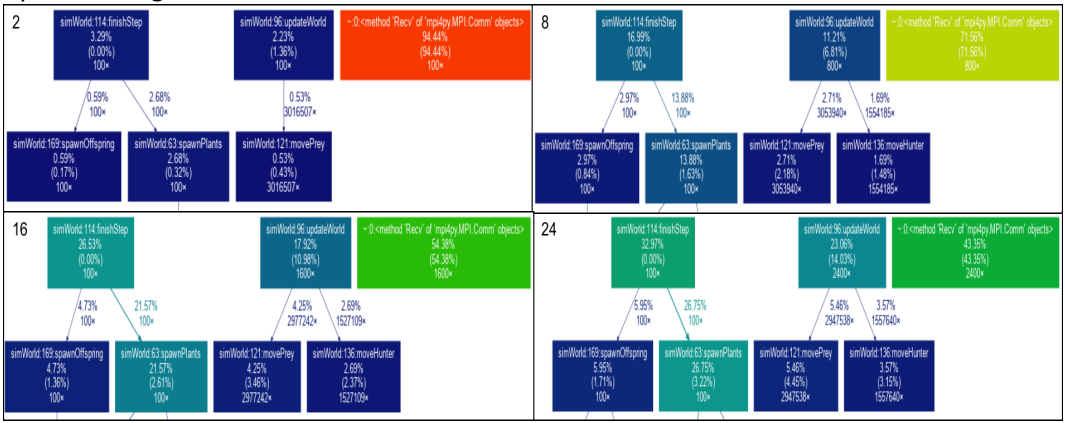
Strong Scaling

Keeping the problem size, increase parallelism



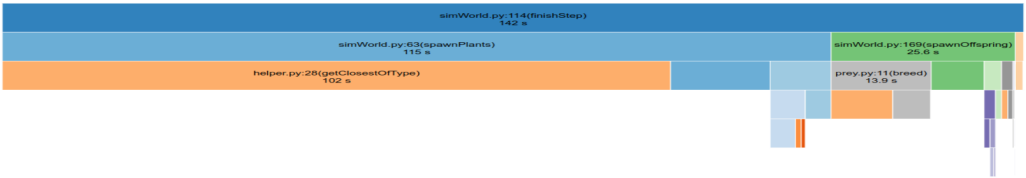
Application Performance

Cpu Profiling - rank 0



Application Performance

Visualizing trace - Snakeviz

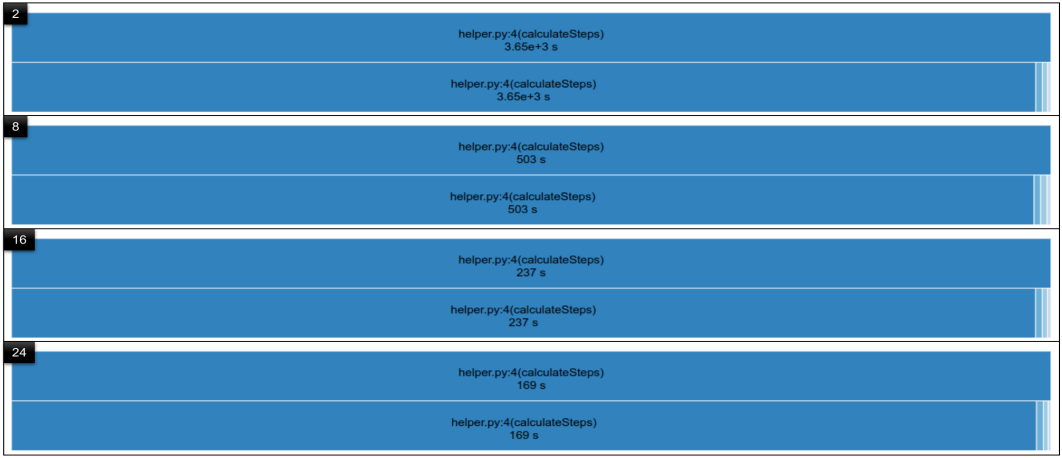


Search:

ncalls	tottime	percall	cumtime	percall	filename:lineno(function)
2400	186.7	0.07778	186.7	0.07778	~:0(<method 'Recv' of 'mpi4py.MPI.Comm' objects>)
2385217	102.3	4.29e-05	102.3	4.29e-05	helper.py:28(getClosestOfType)
2400	60.41	0.02517	99.31	0.04138	simWorld.py:96(updateWorld)
2947538	19.17	6.503e-06	23.52	7.979e-06	simWorld.py:121(movePrey)
100	13.85	0.1385	115.2	1.152	simWorld.py:63(spawnPlants)
1557040	13.57	8.71e-06	15.38	9.872e-06	simWorld.py:136(moveHunter)
100	7.346	0.07346	25.61	0.2561	simWorld.py:169(spawnOffspring)
8599856	5.251	6.106e-07	13.93	1.62e-06	prey.py:11(breed)
6487818	3.575	5.511e-07	8.448	1.302e-06	random.py:290(randrange)
6487818	3.504	5.401e-07	4.872	7.51e-07	random.py:237(_randbelow_with_getrandbits)
4973284	2.077	4.176e-07	2.077	4.176e-07	animal.py:12(setPosition)

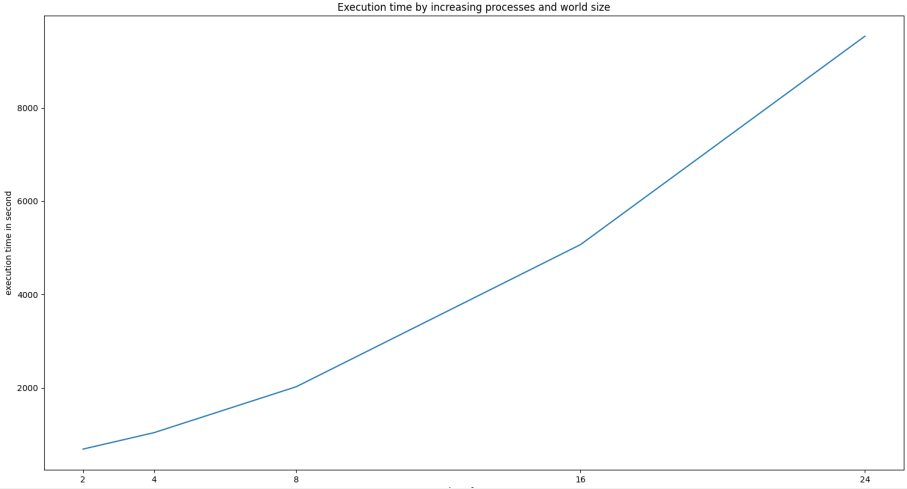
Application Performance

0ther ranks



Weak Scaling

Increase the problem size with parallelism



Future Work

Writing report

Memory Profiling

Change path finding algorithm

Conclusion

Goal: Simulating a predator-prey relationship

Achieve lots of Performance improvements by using mpi