CS 575 Parallel Programming

Project #2

Functional Decomposition

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Description: This project uses parallel programming to perform a month-by-month simulation of grain growth from the start of 2025 to the end of 2030. The growth of grain is by several factors: the number of deer, the number of wolves (the custom quantity I added), and environmental conditions (temperature and precipitation). Parallelism allows each thread to handle a specific task independently. In this simulation, three threads are responsible for computing and updating the number of deer, the number of wolves, and the grain height based on the current state in parallel. An additional thread is used to print the updated state, increment the time, and update environmental variables for the next month. Thus, four threads are used to run the simulation, and the simulation was executed on the OSU Flip3 server.

Commentary:

1. **What your own-choice quantity was and how it fits into the simulation?**

   My own-choice quantity is the number of wolves, which are predators of the deer. Due to the prey-predator relationship, there will be a cyclic pattern between the prey (deer) population and the predator (wolf) population: an increase in one will lead to a decrease in the other, and vice versa. I use the classical Lotka-Volterra model to simulate this ecological interaction between the two animal populations. This model describes the prey-predator relationship with two differential equations for the instantaneous rate of change in each population:

   $$\frac{dx}{dt} = \alpha x - \beta xy \quad , \quad \frac{dy}{dt} = \delta xy - \gamma y$$

   where:

   - x is the current size of the prey population (deer),
   - y is the current size of the predator population (wolves),
   - α is the growth rate of the prey population,
   - β is the death rate of the prey population due to predation,
   - δ is the growth rate of the predator population due to predation,
   - γ is the death rate of the predator population,

- dt represents the time interval per generation. In this simulation, dt is one month per generation, but a generation may span several years in the real ecosystem.

Thus, the addition of wolves can provide direct control over the deer population and indirectly influence the growth of grain, since fluctuations in the deer population caused by the predation will vary grazing pressure on the grain.

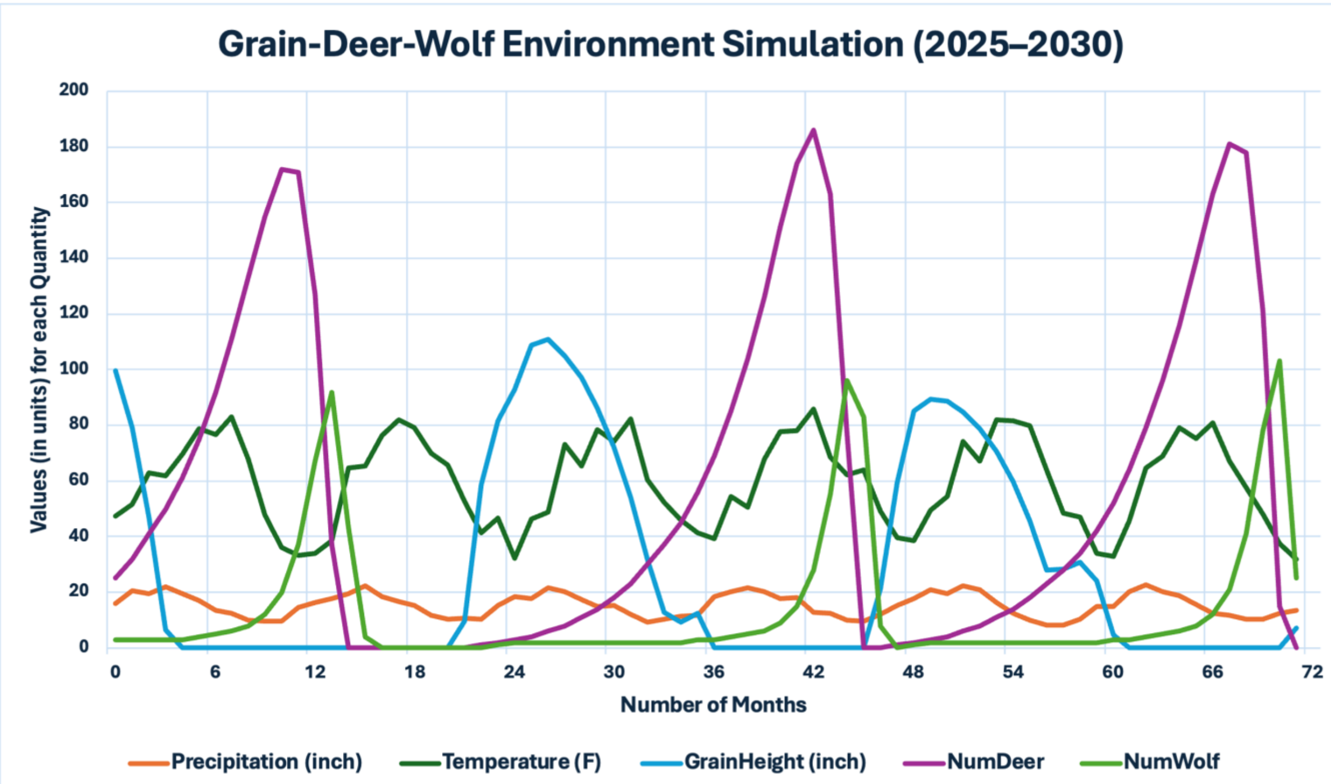
2. A table showing values for temperature, precipitation, number of deer, height of the grain, and your own-choice quantity as a function of month number.

Year	Month	MonthIndex	Precipitation (inch)	Temperature (F)	GrainHeight (inch)	NumDeer	NumWolf
2025	1	0	16.13	47.49	99.61	25	3
2025	2	1	20.44	51.52	79.07	32	3
2025	3	2	19.59	63.06	47.17	41	3
2025	4	3	21.87	61.88	6.27	50	3
2025	5	4	19.46	69.7	0	61	3
2025	6	5	17.07	78.87	0	75	4
2025	7	6	13.5	76.61	0	92	5
2025	8	7	12.42	83.19	0	111	6
2025	9	8	10.07	67.89	0	133	8
2025	10	9	9.63	47.66	0	155	12
2025	11	10	9.73	36.18	0	172	20
2025	12	11	14.66	33.43	0	171	37
2026	1	12	16.16	33.82	0	127	67
2026	2	13	17.68	38.45	0	37	92
2026	3	14	19.67	64.8	0	0	43
2026	4	15	22.15	65.44	0.02	0	4
2026	5	16	18.43	76.39	0.02	0	0
2026	6	17	16.65	82.07	0.02	0	0
2026	7	18	15.34	79.19	0.02	0	0
2026	8	19	11.84	69.99	0.02	0	0
2026	9	20	10.28	65.71	0.09	0	0
2026	10	21	10.77	52.83	9.68	0	0
2026	11	22	10.17	41.52	58.52	1	0
2026	12	23	15.12	46.84	81.62	2	1
2027	1	24	18.35	32.08	92.91	3	2
2027	2	25	17.59	46.38	108.63	4	2
2027	3	26	21.45	48.67	110.99	6	2
2027	4	27	20.19	72.98	104.99	8	2

2027	5	28	17.32	65.43	97.03	11	2
2027	6	29	14.81	78.47	86.03	14	2
2027	7	30	15.33	74.08	72.03	18	2
2027	8	31	12.16	82.19	54.03	23	2
2027	9	32	9.36	60.51	31.78	30	2
2027	10	33	10.25	52.33	12.71	37	2
2027	11	34	11.43	46.11	9.44	45	2
2027	12	35	11.6	41.31	12.34	56	3
2028	1	36	18.28	39.43	0	69	3
2028	2	37	20.13	54.47	0	85	4
2028	3	38	21.75	50.51	0	104	5
2028	4	39	20.21	67.98	0	126	6
2028	5	40	17.91	77.9	0	151	9
2028	6	41	18.07	78.12	0	174	15
2028	7	42	12.77	85.9	0	186	28
2028	8	43	12.33	68.72	0	163	55
2028	9	44	9.95	62.18	0	77	96
2028	10	45	9.56	63.95	0	0	83
2028	11	46	12.19	49	21.18	0	8
2028	12	47	15.14	39.47	59.46	1	0
2029	1	48	17.81	38.65	85.13	2	1
2029	2	49	20.89	49.54	89.28	3	2
2029	3	50	19.66	54.47	88.7	4	2
2029	4	51	22.48	74.18	84.7	6	2
2029	5	52	20.77	67.1	78.71	8	2
2029	6	53	16.28	82.14	70.71	11	2
2029	7	54	12.57	81.71	59.71	14	2
2029	8	55	9.99	79.86	45.71	18	2
2029	9	56	8.11	64.12	27.85	23	2
2029	10	57	8.31	48.57	28.15	28	2
2029	11	58	10.42	46.99	30.78	34	2
2029	12	59	15.07	34.07	23.98	42	2
2030	1	60	15.06	32.74	4.85	52	3
2030	2	61	20.28	45.77	0	64	3
2030	3	62	22.54	64.52	0	79	4
2030	4	63	20.33	68.87	0	96	5
2030	5	64	18.72	79.14	0	116	6
2030	6	65	15.48	75.2	0	139	8
2030	7	66	12.42	81.01	0	163	12
2030	8	67	11.69	67.19	0	181	21
2030	9	68	10.38	57.69	0	178	41

2030	10	69	10.18	48.11	0	121	78
2030	11	70	12.56	37.35	0	15	103
2030	12	71	13.53	31.73	7.28	0	25

3. **A graph showing temperature, precipitation, number of deer, height of the grain, and your own-choice quantity as a function of month number.**



4. **A commentary about the patterns in the graph and why they turned out that way. What evidence in the curves proves that your own quantity is actually affecting the simulation correctly?**

   Although the generation interval has been shortened to one month for convenience, the simulation results in the above graph show clear cyclic patterns for each quantity that align well with the theoretical ecological patterns:

   - ***Precipitation and temperature show a distinct seasonal pattern that matches the real-world weather***. Temperatures are low in winter, rise steadily in spring, peak in summer, and then decline in fall. Precipitation is moderate to high during spring and fall with a relatively drier summer. Such clear seasonal variations shown in every year of the simulation match the characteristics of the humid continental climate.

- ***Grain growth is directly impacted by temperature, precipitation, and the number of deer***. In this simulation, I set the optimal growth conditions for the grain at 40°F and 10 inches of precipitation (a cool-season grain). We can observe that grain height increases at a high rate from November to December in both 2026 and 2030 when temperature and precipitation are close to the optimal. When the deer population is high, the grain height declines significantly due to increased grazing pressure. This explains why grain growth is halted or suppressed even with the optimal conditions during winters in other years.

We can also observe that the addition of wolves in the simulation impacts both the deer population and the growth of grain as expected:

- ***The introduction of the wolf population appropriately produces the expected predator-prey population cycles***. We can observe that the populations of deer and wolves oscillate in a cyclic pattern over the simulation from 2025 to 2030. When the deer population reaches a peak, the wolf population soon increases due to greater prey availability. As predation intensifies, the deer population shrinks. A subsequent decline in the wolf population then occurs once the prey becomes scarce. This cyclical rise and fall occurred nearly three times in these six years, which is consistent with the expectations in the Lotka-Volterra model.
- ***The wolf population indirectly promotes the growth of the grain by controlling deer populations***. When the number of wolves is low and the grain is tall, the deer population enlarges rapidly due to reduced predation and enough food resources. Inversely, when there are only a few wolves and grain is abundant with a high height, the deer populations grow rapidly due to less predation, and grain growth slows or even reverses due to intensified grazing pressure.