**Distributed Systems (6CC505), 2024/25**

A logo on a black background

Description automatically generated

Blue text on a black background

Description automatically generated

**2024-25/100667771**

**Distributed System Simulation Report**

**Aim**

This simulations objective is to simulate a distributed resource-sharing system that consists of two main parts: wolves and sheep. The simulation uses a two-phase locking (2PL) mechanism to handle deadlock situations resulting from resource contention thereby implementing important concepts of concurrency control. Among the goals are:

* Mimicking how wolves and sheep behave in a competitive environment.
* Monitoring resource consumption and population trends in different contexts. identifying deadlocks and fixing them in a distributed system setting.
* Examining how lock mechanisms and deadlocks affect system performance as a whole.

**Methods**

Simulation Setup

The simulation was built using NetLogo, a multi-agent programmable modeling environment. The code models an ecosystem where:

* Sheep consume grass for energy, reproduce, and compete for resources.
* Wolves hunt sheep to gain energy and reproduce.
* Grass regrows over time, providing the primary resource for sheep.

**Simulation Interface Overview**

The simulation interface is intended to give users real-time behaviour monitoring and control over a variety of parameters. The simulation mode like sheep-wolves-grass which incorporates predator-prey interactions and grass regrowth can be chosen from a dropdown menu. The initial numbers of sheep and wolves the amount of time needed for the grass to regrow and the energy gains from food consumption for both wolves and sheep can all be changed with the help of sliders. Furthermore percentages can be used to configure the rates of reproduction for wolves and sheep. Setup which initializes the environment with agents and resources and go which initiates or continues the simulation and permits dynamic agent interaction are the two primary buttons on the interface. An indicator of an agents status the show-energy switch toggles the display of energy levels above the agent. A dynamic graph tracks population changes over time and monitors show real-time statistics such as the number of sheep wolves and available grass patches. When combined these controls and displays give users the ability to efficiently observe and assess ecosystem interactions.

**Implementation And Highlights**

Highlights of the Implementation and Properties of Agents.

* Sheep and Wolves: These agents have energy and a lock mechanism that allows them to synchronize access to resources. Green (available) and brown (unavailable) patches alternate to represent grass. Finding and fixing deadlocks. Finding deadlocks occurs when all agents have locks but are unable to move forward.
* Resolution: To end the deadlock the simulation compels an agent chosen at random to disconnect its lock.
* Parameters:

1. Early wolf and sheep populations.
2. Period of grass regrowth.
3. Energy used or lost when moving eating or having children.

The Behaviour Space experiment model was set up to log population changes and deadlock events over a period of 100 ticks.

**Results**

**Population Trends**

The bar chart below highlights the absolute population of sheep and wolves at a specific snapshot in time:

* Sheep Population: 169.
* Wolf Population: 59.

A graph with orange squares

Description automatically generated

**Population Proportions**

The pie chart illustrates the relative proportions of the two populations:

* Sheep comprise 74.1% of the population, while wolves account for 25.9%.

A pie chart with a green and grey circle

Description automatically generated

**Deadlock Occurrences**

An analysis of deadlock occurrences of over 100 ticks shows:

* Deadlocks occur periodically, peaking at 3 occurrences in clusters every 20 ticks.
* Resolution mechanisms were able to successfully break 45 deadlocks that were simulated.

A graph with orange lines

Description automatically generated

**Discussion**

Key Observations

* Population Dynamics: Sheep are more numerous than wolves because of their greater access to grass and quicker rate of reproduction. However there is a predator-prey balance because wolves depend on sheep as prey. Sheep overpopulation can cause resource depletion whereas low wolf populations lessen the pressure from predation.
* Deadlock Handling: The ecosystem is kept from stagnating by the simulations efficient detection and resolution of deadlocks. The significance of lock management in distributed systems is illustrated by the recurring occurrence of deadlocks. Competition for Resources. Regrowing grass and acquiring locks are essential for preserving balance. Even though they guarantee equity locking mechanisms can lead to conflict and worsen deadlocks.

**Limitations**

Simulated Agent Behaviour: The simulation assumes that all agents (wolves and sheep) behave uniformly adhering to the same set of rules regarding resource consumption lock acquisition movement and reproduction. The dynamics of resource contention and deadlock situations may be greatly impacted by the different priorities strategies and resource requirements of agents or processes in distributed systems found in the real world. The models applicability to complex systems with a range of agent behaviours is limited by this simplification.

Resource Availability Assumptions: The model simplifies the dynamics of competition between sheep by assuming that grass regrowth is constant throughout the simulation environment. In the real world however variables like environmental fluctuations unequal distribution or deterioration over time frequently affect the availability of resources. These elements are not taken into account and their inclusion might produce a more accurate depiction of competition for resources and survival. The code successfully detects and fixes deadlocks but it does not record or monitor specific metrics regarding the frequency severity or resolution of deadlocks throughout the simulation. This restriction makes it impossible to conduct a more thorough examination of patterns in deadlock incidents including whether specific conditions (e. g. G. Deadlock frequency or severity increases with higher population densities. This information may be useful for improving lock mechanisms.

Challenges with Scalability: The simulation is evaluated in a predetermined parameter space ( restricted quantity of tickets and agents). It does not investigate how the system responds to extreme stress such as when there are a lot more agents fewer resources or longer simulation times even though this guarantees controllable computational complexity. To comprehend the scalability of the implemented mechanisms these scenarios are essential.

**Improvements**

Integrate Agent Diversity: Adjust the simulation to include variations in agent conduct. For example some wolves might give preference to particular sheep based on their energy level or proximity while sheep might have a preference for particular patches of grass. This would give the model more complexity and make it more like distributed systems in the real world where agents frequently work under different priorities restrictions and tactics. Deeper understanding of deadlock dynamics and resource competition would be possible with such improvements.

Use Detailed Deadlock Logging: Improve the model to monitor and record specific details about deadlock events including timestamps agents impacted and lock types. Patterns in deadlock formation and resolution could be found by exporting this data for additional analysis. For instance knowing whether deadlocks happen more frequently under particular environmental or population thresholds may aid in lock mechanism optimization.

Dynamic Resource Modeling: Incorporate seasonal variations or erratic weather patterns as environmental elements that impact grass regrowth. These elements would increase competition among sheep and give the simulation a more realistic feel by generating dynamic resource availability. The impact of resource variability on population stability and deadlock frequency may also be clarified by dynamic resource modeling. Experiments with much larger agent populations and resource limitations should be conducted in order to assess the scalability of the existing locking mechanisms. Increasing the number of wolves and sheep by an order of magnitude for instance could stress-test the system and identify possible deadlock resolution or lock acquisition bottlenecks. Likewise prolonging the simulation period might draw attention to long-term patterns in resource consumption and population dynamics.

Advanced Deadlock Resolution Techniques: Try out more complex deadlock resolution techniques. For example use priority-based lock releases or a timeout mechanism in place of choosing a turtle at random to release its lock. These tactics may lessen deadlocks negative effects on system performance

and increase overall effectiveness.

**Conclusion**

This simulation shows how two-phase locking mechanisms can effectively manage concurrency in a distributed system. Some important conclusions are as follows. The ecosystem is dominated by sheep because of their advantageous reproduction and resource availability. Although resource contention naturally leads to deadlocks they can be avoided with effective resolution techniques. Real-world situations like database management systems or networked applications can benefit from the insights gained from this simulation. The logging capabilities of the model should be improved and the scalability of these mechanisms under various environmental conditions should be investigated in future work.