A New Biologically Inspired Consensus Algorithm for Multi-Agent Systems Based on Turtle Hatching

Austen Pallen[1] | Dr. Bryan Watson[2]

1. Department of Physical Sciences, Embry-Riddle Aeronautical University
2. Department of Electric Engineering and Computer Science, Embry-Riddle Aeronautical University

Abstract

New technologies rely on multi-agent systems (MAS's) and their ability to achieve consensus. Current distributed consensus approaches, however, have narrow applicability and are only resilient to a small subset of faults. Biologically Inspired Design may provide the inspiration needed to develop more applicable consensus algorithms. Our hypothesis is that if the biological behavior of synchronous turtle hatching is evaluated, then a more resilient and novel consensus algorithm can be developed, because current turtle hatching requires resilient consensus for species survival. To test this, an Agent-Based, ANYLOGIC model was developed based on the turtle behavior and tested against 1, 5, 10, 15, and 20 faulted agent(s) across four different environments. The time taken for 66% of the agents to accurately reach consensus about environmental conditions was recorded. There were 50 runs per faulted agent per environment totaling 1,200 runs. The agreement time average for the tests that consistently reached the consensus limit had coefficients of variance below 3%, showing resilience to faulted agents and proving that the proposed distributed consensus algorithm was resilient to faulted agents (even up to 20% of the population). Additionally, the results provide insight into the type of scenario the algorithm can be applied to (minimum viable parameter rate of change requirement).

Research Question

How can the biological phenomena observed in the **Podocnemis Expansa (Giant South American River turtle)** during their nesting periods, be applied to modern consensus problems within MAS's?

Purpose

- Develop distributed consensus algorithm based on hatching behaviors

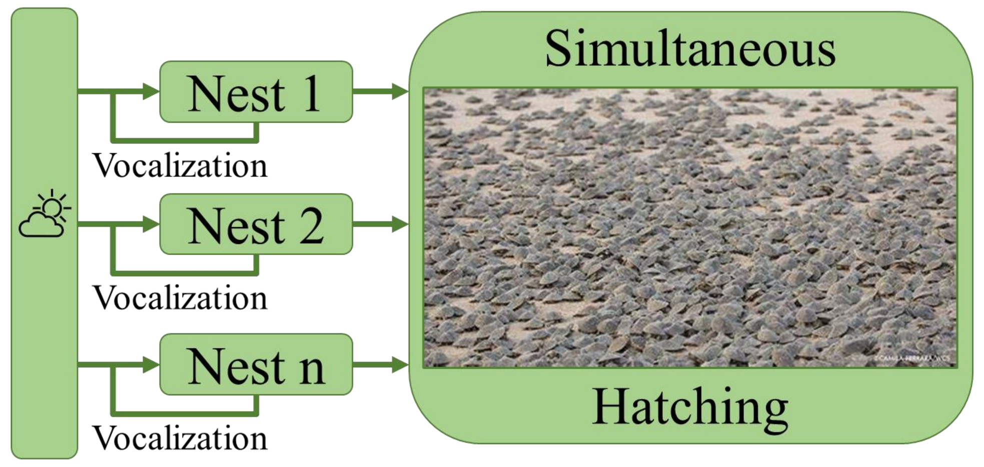

Figure 1: The emergent hatching behavior based on modular consensus

Hypothesis

If the biological behavior of synchronous turtle hatching is used as inspiration for a consensus algorithm protocol, then that protocol will be an effective consensus solution, because current turtle hatching behaviors are modular and robust.

Model Description

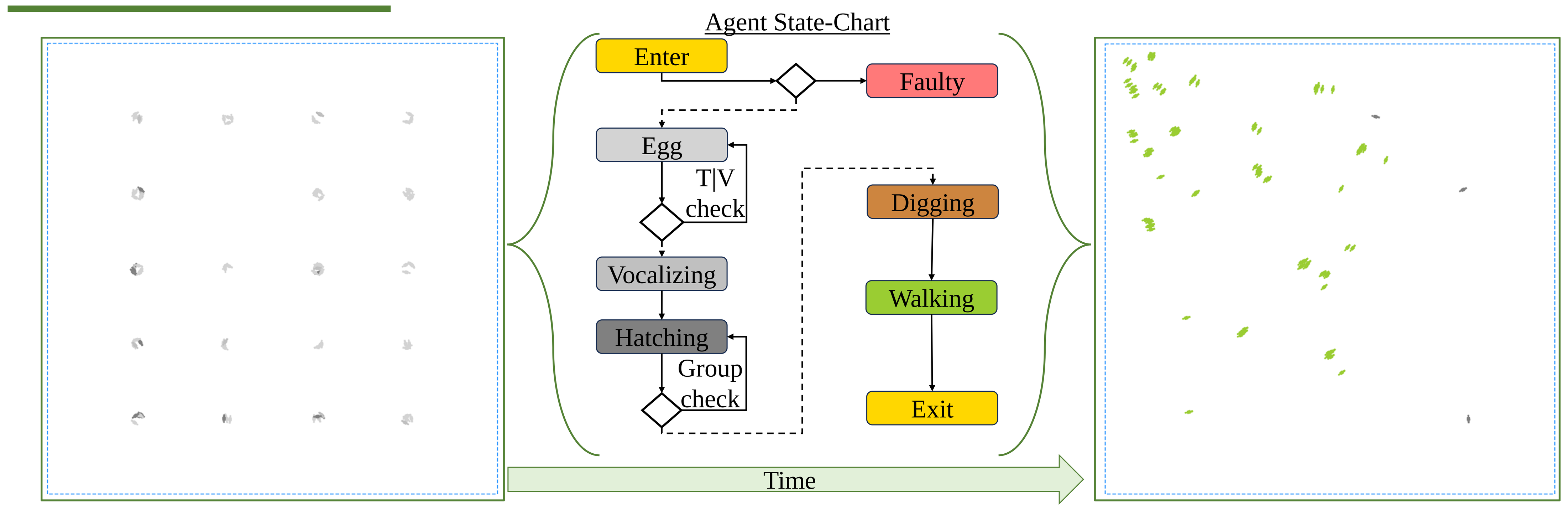

Figure 2: The Agent-Based Model is initializing in the left image. 100 agents evenly distributed to 20 nodes (nests). Each agent has the same state-chart than they progress through. If enough agents pass their T|V checks and then their Group Checks around the same time then, the emergent behavior in the right image may occur.

Agent Properties		
State	Vibration Probability	Vibration Level
Egg	0.03	1
Hatching / Faulty	0.2	2
Digging	0.75	3
Walking	1	4
Done	0	0

Table 1: the likelihood that an agent will create a vibration, and the normalized strength of that vibration are determined by the state the agent is in.

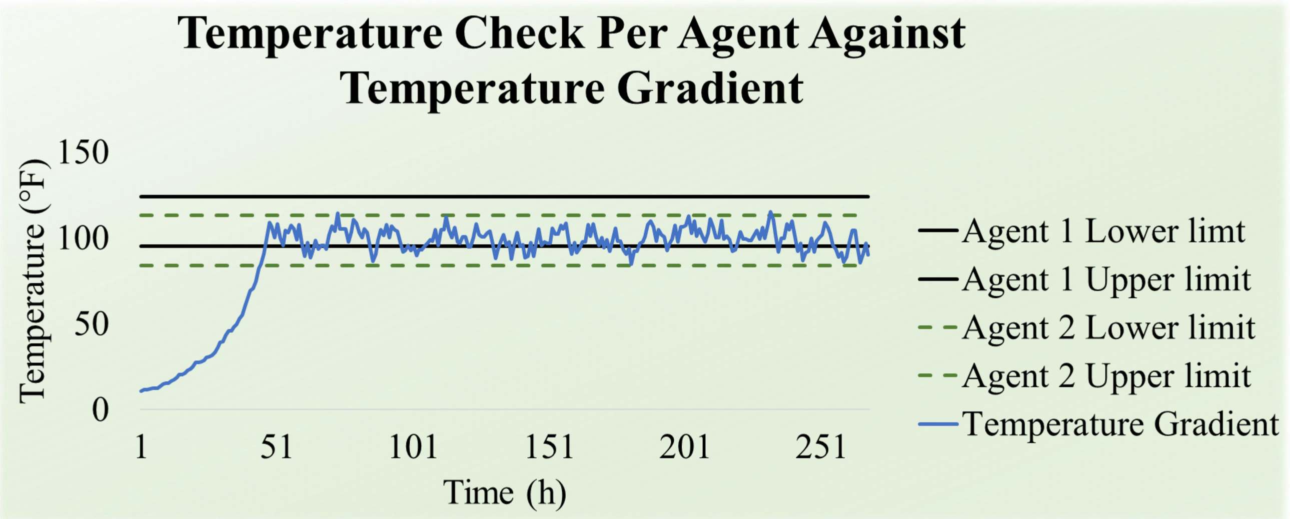

Figure 3: the positive environment range is different for every agent. If the temperature is within these ranges, then the agents increase their odds of progressing through their state-charts.

Model Data

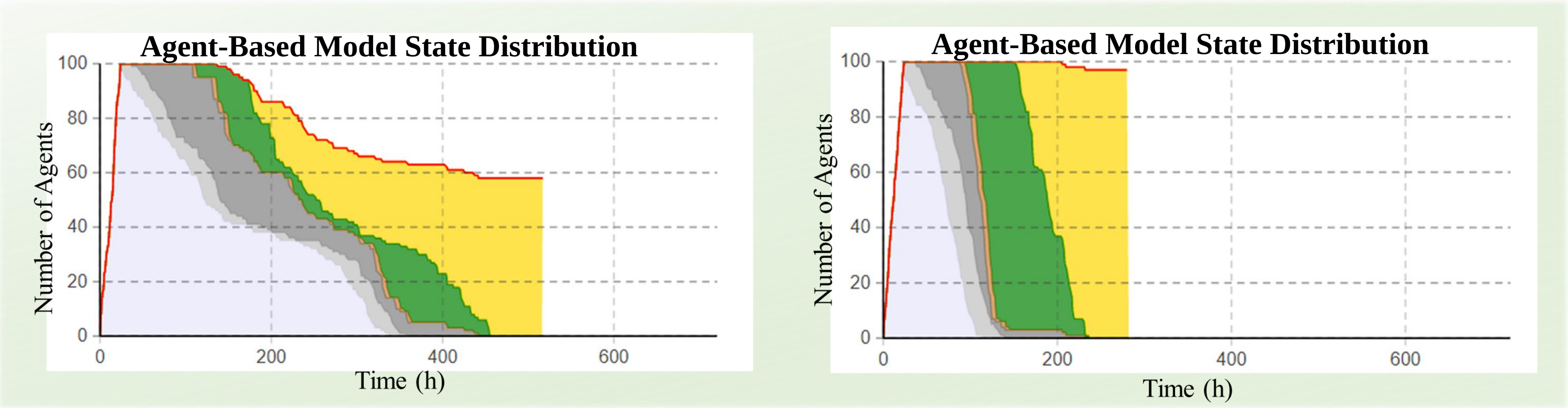

Figure 4: two different emergent behaviors demonstrated via time-stack charts are shown. The stack charts show the number of agents within every state in the state-chart from figure 2 at any moment in time. The colors match the respective states from the state-chart. These tests have no faulty Agents. The left-hand side chart shows a slow response and the loss of agents as a result, and the right-hand side shows a fast response and little loss.

Future Iterations

- Application to Search and Rescue testbed
- Increased emphasis on modular representation (100 agents per node)
- Random destination
- Evaluation of resilience at Group Check

Results

	Average Time to 66% Consensus (h)					
Number of Faulted Agents:	0	1	5	10	15	20
Temperature Gradient						
1.00-1.05	125	189	193	303	392	378
1.05-1.10	257	261	258	252	248	248
1.10-1.15	219	219	218	214	211	208
1.15-1.20	219	219	218	214	211	208

Table 2: average times, for the model to reach a two thirds consensus, of the 50 runs per faulted agent, per temperature gradient (1,200 total runs).

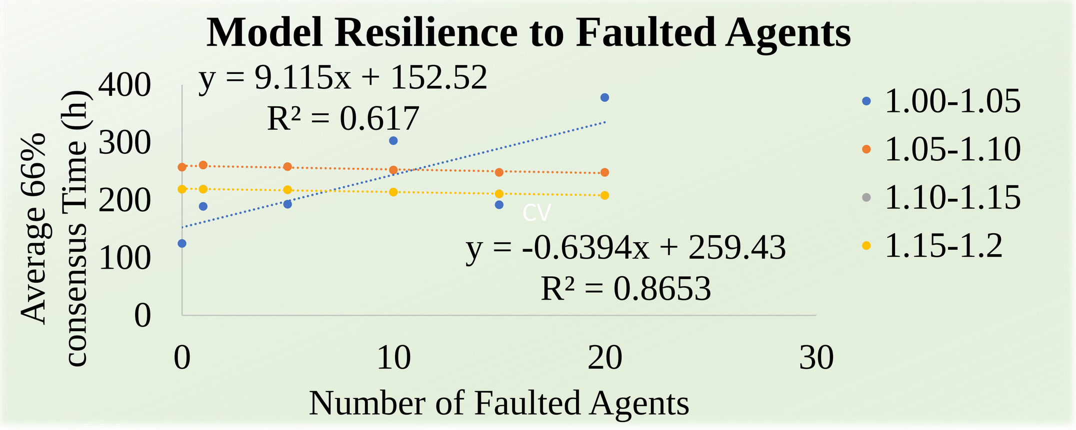

Figure 5: the upper equation represents the average 66% consensus time as a function of the number of faulted agents while in the "1.00-1.05" temperature gradient, while the lower equation represents the same for the "1.05-1.10" temperature gradient.

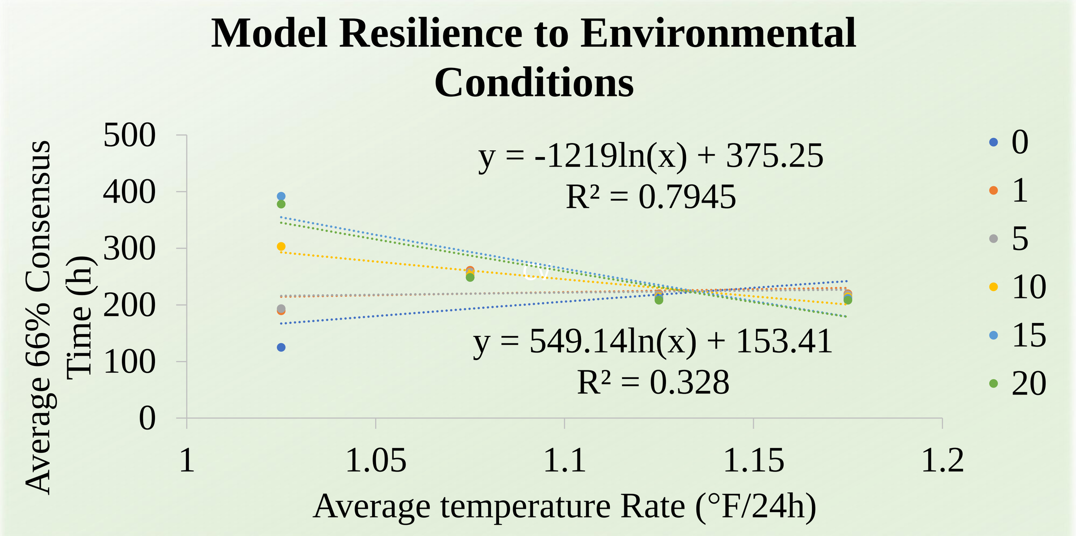

Figure 6: the upper equation represents the average 66% consensus time as a function of the average temperature rate for 20 faulted agents, while the lower equation does the same for 0 faulted agents.

Temperature Gradient	Coefficient of Variance of Average 66% consensus times
1.00-1.05	41.9
1.05-1.10	2.1
1.10-1.15	2.1
1.15-1.20	2.1

Table 3: Statistical evaluation of the model's resilience to faulty agents per the temperature gradient.

Conclusion

- The biological inspiration can be used to develop a multi-agent model hat is robust/ resilient to faulty agents
- Model is not resilient at the temperature gradient "1.00-1.05"
- Model needs addition testing to determine resilience to environmental conditions

Biologically Inspired Design-for-Resilience Lab

Contacts

Dr. Bryan Watson: watsonb3@erau.edu
Austen Pallen: pallena@my.erau.edu