Developing A Novel Consensus Algorithm Based on Synchronous Turtle Hatching

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Abstract

Many new technologies rely on multi-agent systems (MAS) and their ability to achieve consensus. Failure for these systems to reach consensus can result in the loss of life, money, and public trust. Therefore, we need to have resilient consensus algorithms, but current approaches have narrow applicability and are only resilient to a small subset of faults. Biologically Inspired Design (BID) may provide the inspiration needed for new 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 behaviors require resilient consensus*. A literature review of turtle hatching behavior was conducted in order to develop an accurate conceptual turtle hatching model via the ODD protocol (Overview, Design concepts, and Details). The completion of the ODD protocol marks the end of the finished work. This poster presents the results of that literature review and the ODD protocol demonstrating that the turtle shell-hatching process is resilient and can be developed into a testable model. Future work will focus on developing the computer model within AnyLogic to tests impact of single agent failure and comparing modern consensus algorithms to the turtle-based approach.

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?

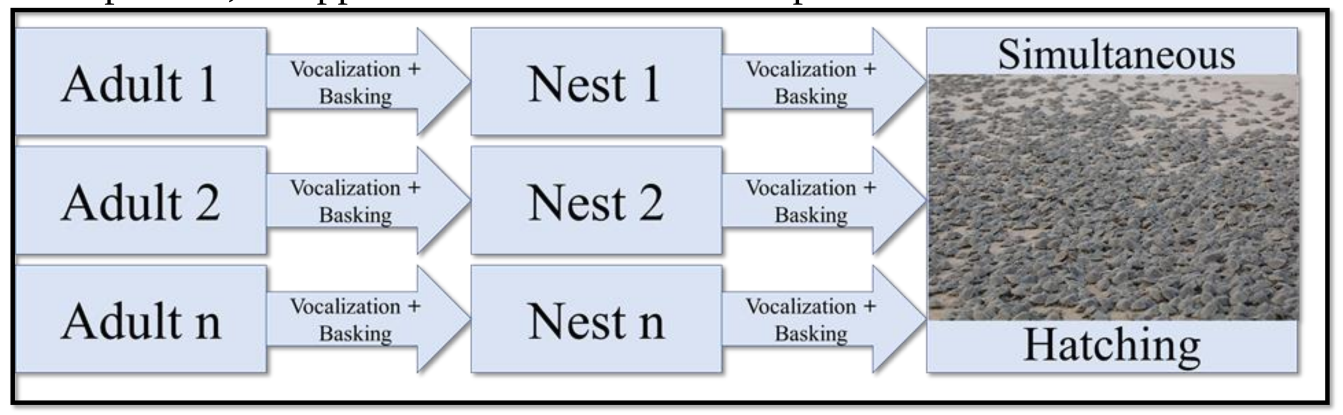

Figure 1. shows synchronous behaviors during nesting period

Hypothesis

We Hypothesize that if the synchronous nesting behaviors of turtles are evaluated, then a more resilient and novel consensus algorithm can be developed, because the current turtle hatching behaviors require resilient consensus to be evolutionarily viable.

Developing the Turtle Model via ODD Protocol

The Purpose of following the ODD protocol was to ensure that the resulting Agent Based Model (ABM) is an accurate, extensive and repeatable model.[1] The protocol involves the identification of the model's topic, purpose, significance and Hypothesis. These were used alongside the information gained from the leading literature on the *P. Expansa* to complete the ODD protocol in **figure 2** below:

Overview	**Purpose:** What should this model solve?	What Conditions Impact Synchronized Nesting Season?
	Entities; Things represented in model: Agents, Local Environment, Global Environment	Turtles: Embryo, Hatchling and Adult Local Environment: Egg, Nest, Surface and River
	State Variables: Agent properties and behavioral strategies **(S)** Static **(D)** Dynamic	Turtles: Vocalization Frequencies (D) and Vocalization Likely hoods (D) Environment: Sound (D) and Vibration (D) Permeabilities, Temperature (D)
	Scales: Temporal and Spatial (Range and Smallest Step)	Temporal: 36-75 Days, Day or Hour step depending on stage Spatial: 5 km, km-cm steps depending on stage
	Process Overview and Scheduling: A succinct Description of each of the processes executed by the model's entities.	Coordination and Basking by Adults Temperature Regulation by Nest/Eggs Coordination of Hatching and Emergence by Hatchlings Migration Coordination by Hatchlings and Adults
Design	**Basic Principles:** Theories/ Hypothesis that underly model approach	Vocalization Leads to Coordination
	Emergence: Important results/outputs are they emergent?	Coordination
	Adaptation: How to agents adapt, how is that modeled?	Vocalization: Rates of Vocalization, Frequency of Vocalization Change in Environment: Vocalization Count Across Environment
	Objectives: What are the agent objectives that drive adaptive behavior?	NA (Instinct)
	Learning: Do agents change their behavior as a result of experience, how?	NA (Instinct)
	Prediction: Do agents make predictions about their future environment? What inputs (learning, sensing) affect this?	NA (Instinct)
	Sensing: What can agents sense? What sensing inaccuracy? What variables do agents just "know"	Vocalization Frequency Prioritizing Lower Frequencies, and Then Environment State,
	Interaction: How do the agents interact? What real-world mechanism is this based on?	**Hatchling Behaviors are Increased by Reception of Vibrations and Vocalizations** Adults are Attracted to Hatchling Vocalizations (Contact Calls)
	Stochasticity: How are stochastic processes used? - Model Initialization?	Probability of Vocalization (too Intensive to Know Which Hatchling is Vocalizing Within Nest) Temperature by Day (may be Ignored Based on Variance)
	Collectives: Are aggregates of agents significant?	Groups Based on Sates are More Successful with Size Sorting of Turtles (Within States): If they Have Vocalized is Unnecessary
	Observation: What does the model output? What is needed for testing and validation?	Vocalization Rate, Time to Change Environments
Details	**Initialization:** Number of agents, agent states, environmental variables.	Random Nest Sizes Centered Around 30 **Eggs** (initial environment) Nest Sizes From Groups Studied By Ferrara, et al.
	Input Data : Read in data (environmental conditions) sources?	Temperature Over Nesting Season (potentially) Constant Conditions (permeability, and Agent presence)
	Sub-models: All equations, logical rules, flow charts for independent sub-models in model.	Nest Temperature Distribution: Size vs Hatching Time Propagation of Vocalizations Within Environments (Compounds Impact of Agent Numbers and Environment permeability)

Figure 2. ODD protocol from ***The Craft of Research and Agent-Based and Individual Modeling: A Practical Introduction***

Turtle behavior

Nesting Period

- Female coordination towards suitable nesting sites (cohesive groups of 100) [3]

Figure 3. Shows synchronous behavior among adult female turtles

- An individual female can lay up to 100+ eggs/year but only about 30 eggs/nest[3]
- Hatching period of 36 to 75 days [3]
- Eggs diffuse temperature across nest (ensuring universal hatching period), cooling the eggs closer to the surface and heating the eggs near the bottom of the nest
- Embryos begin vocalizing 8-36 hours prior to hatching[2]
- Vibrations and vocalizations cue hatching, communal digging and emergence [2]
- Vocalizations between mothers, mothers and embryos/hatchlings (surface, nest and water vocalizations)
- Females and hatchlings migrate to flood plains together

Vocalizations

- Hatchlings exhibit lower vocalization rates and higher vocalization frequencies [2]
- All vocalization rates are increased based on the size of a nest

Conclusions

- Turtle Synchronous behavior demonstrates consensus
- A turtle nesting season can be applied to an ODD protocol in which the communication parameters are the main driver for the success of the season, otherwise referred to as fitness.

Future Considerations

- Development of computer model to test for impact of single agent failure
- Comparison of current consensus algorithms to the turtle-based method
- Further computer model development to test against other conditions

Works Cited

1. Railsback, Steven F. *Agent-Based and Individual-Based Modeling : A Practical Introduction, First Edition.* Princeton University Press, 2012.
2. Ferrara, Camila R., et al. "Sound Communication in Embryos and Hatchlings of Lepidochelys Kempii." *Chelonian Conservation and Biology*, vol. 18, no. 2, 26 Nov. 2019, p. 279, https://doi.org/10.2744/ccb-1386.1. Accessed 10 May 2022.
3. ---. "Turtle Vocalizations as the First Evidence of Posthatching Parental Care in Chelonians." *Journal of Comparative Psychology*, vol. 127, no. 1, 2013, pp. 24–32, www.seaturtle.org/PDF/FerraraCR_2013_JCompPsychol.pdf, https://doi.org/10.1037/a0029656. Accessed 15 May 2020.

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