

Energetic Analysis of Tagged Sea Turtles Using Geomagnetic Navigation

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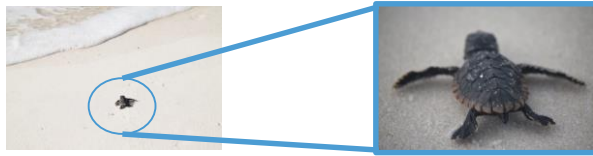


Want to understand LONG distance sea turtle migration

- Important and interesting scientifically
- May have applications in engineered systems

Takes a lot of energy

- Turtles typically eat to build up fat stores, then execute reproductive migration with LIMITED foraging





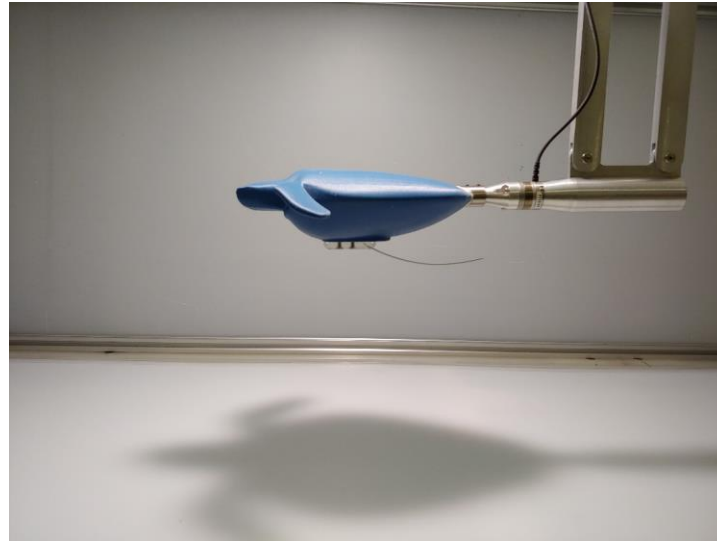
Turtle migration and energetics are HARD to study!!!

- Where they go affects what they eat which affects metabolism → where do they go?
 - Use platform terminal transmitters (PTTs)!
 - Adds drag to the turtle
 - Bigger tags that can tell us more may be a bigger problem
 - Tags can fail, because – technology...
 - Typically apply to juveniles, but tags have a shelf life due to various factors (e.g., external factors, turtles grow, etc...)
 - Various indirect methods for studying energetics
 - Isotope analysis
 - Different modeling approaches
 - Scaling of results from juveniles
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The Problem (with tags...)



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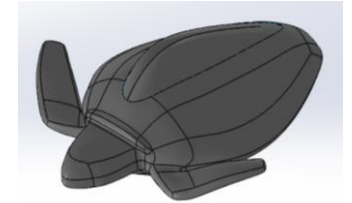
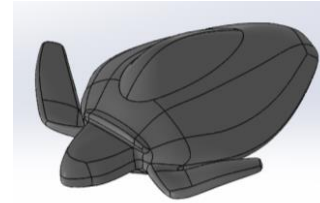
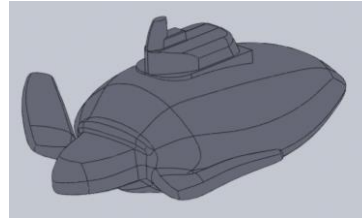


The Problem (with tags...)

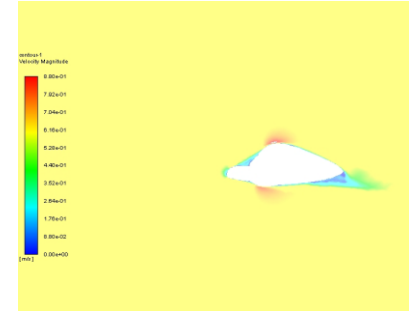
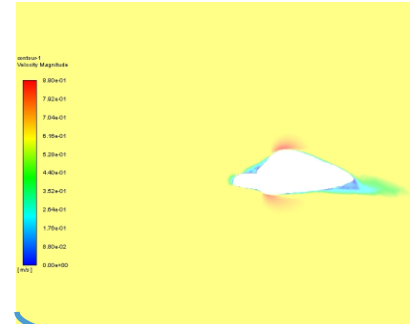
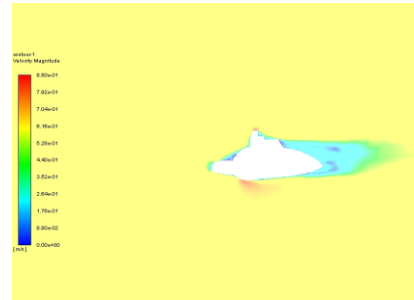


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Computer Aided
Design (CAD)




Computational Fluid
Dynamics (CFD)

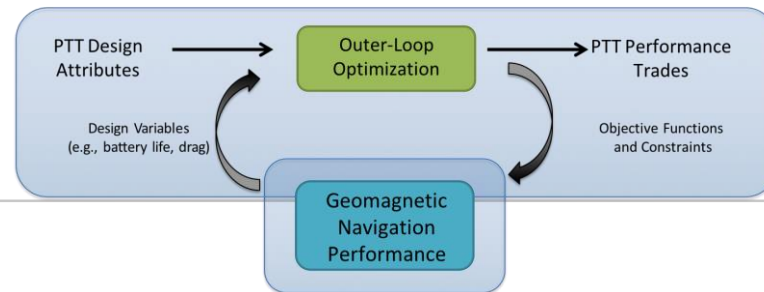


LOTS of drag

Less drag (2 different new designs)

Use modeling to evaluate the effects of different tags & select an optimal tag for a given task

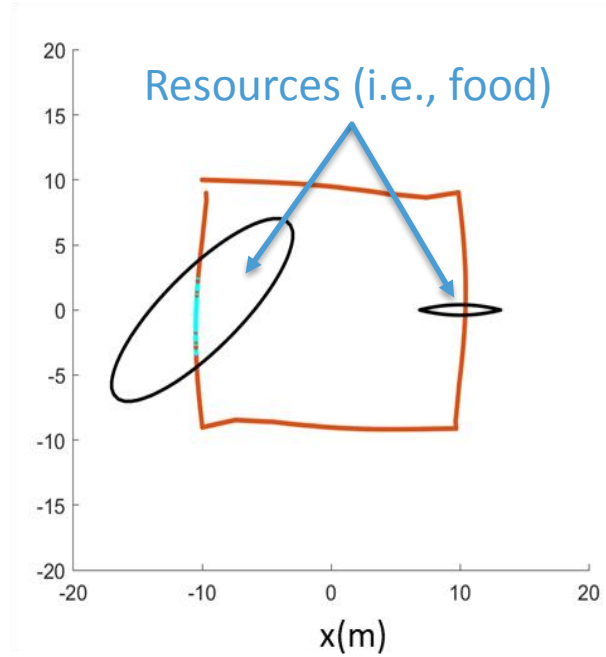
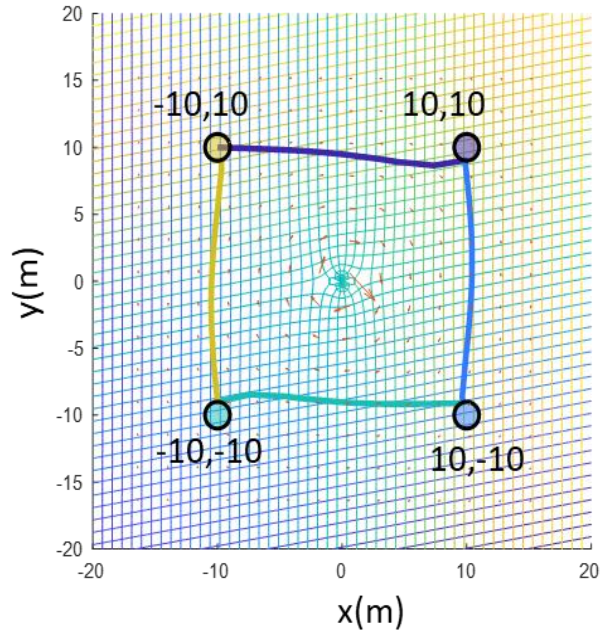
- Set input parameters (e.g., Drag coefficient, area, battery life, etc...)
- Agent based model (ABM) runs via. magnetoreceptive migratory behavior and computes energy expended & consumed 
- Feed results to a simulated-annealing-based optimizer
- Rinse & Repeat



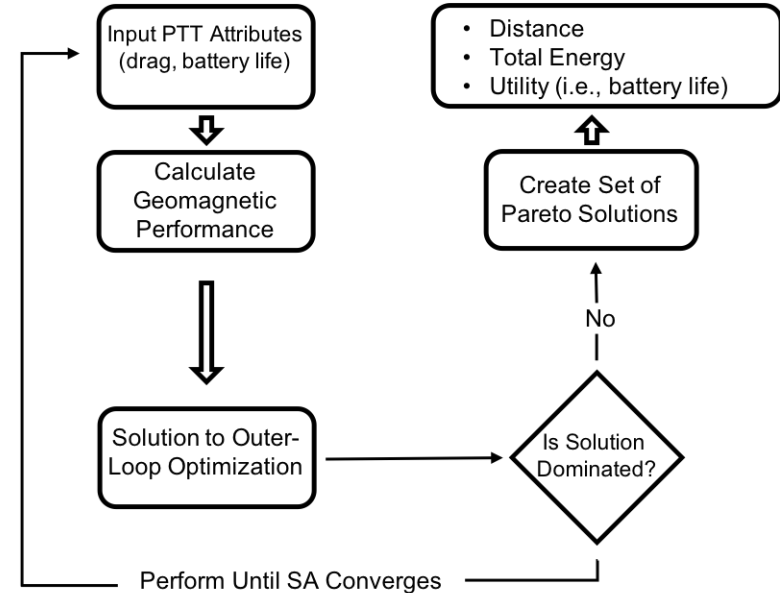
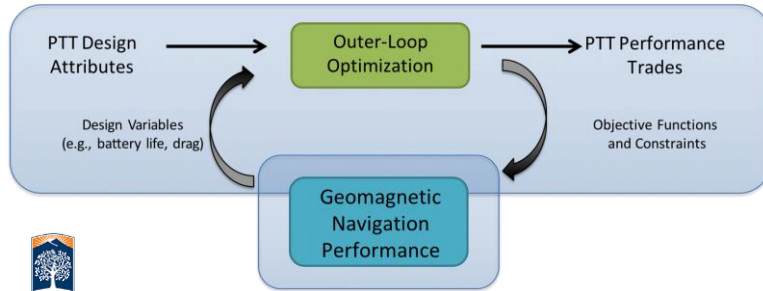


- Approach being used in understanding animal magnetoreception and navigation (Taylor 2018, Taylor and Corbin 2019)
 - Migrates to 4 points
 - Can consume resources (i.e., food) en route with probability in certain locations
 - Expend power/loses energy when there are no resources
 - Gains energy when there are resources
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Agent-based model

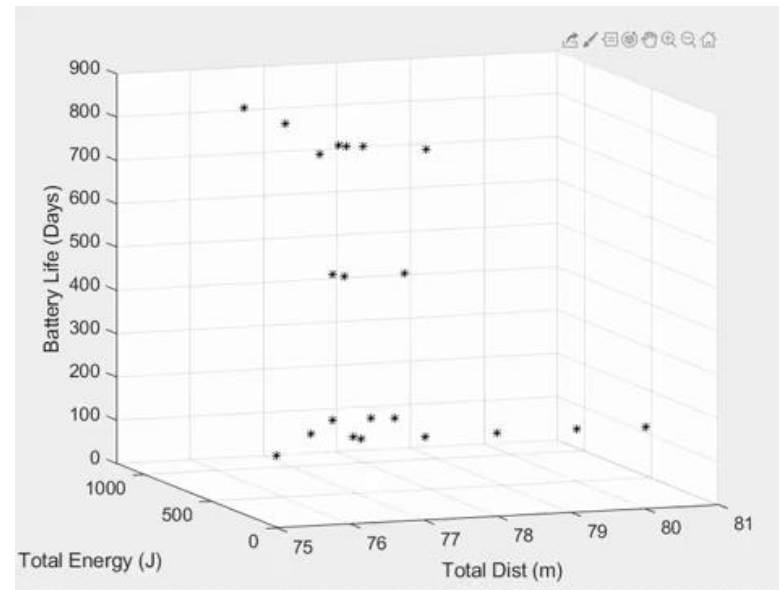
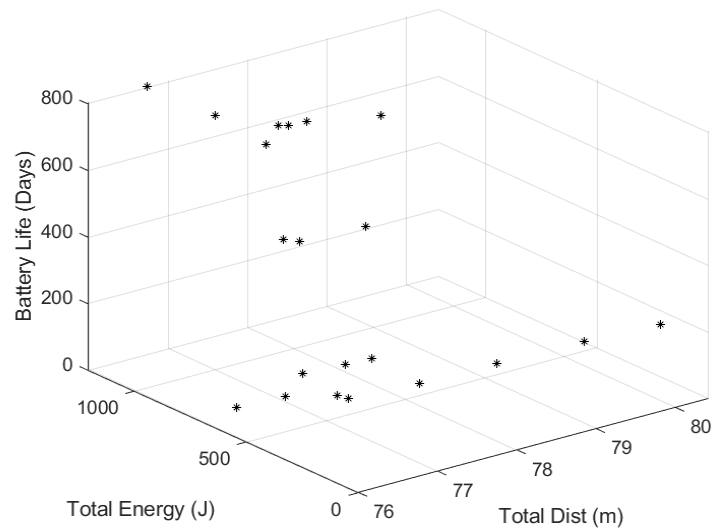


Optimization Framework



$$U_a = P_0 u_{battery}(x_1) + (1 - P_0) u_{battery}(x_2)$$

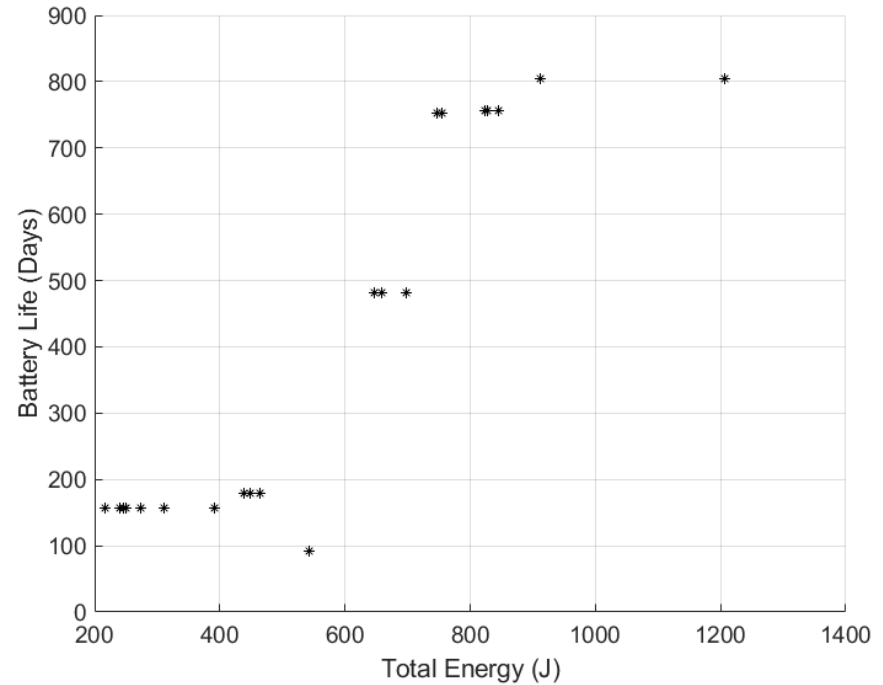
Results



Results



- Longer battery life (i.e., bigger tag) = More energy expended
 - Expected result – verifies our approach
- Agents take similar paths, but bigger tags expend more energy
 - Expected result – verifies our approach



Results



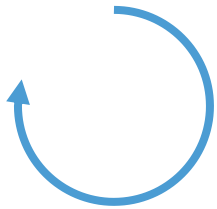
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Description	PTT ID	Distance (m)	Energy (J)	Utility	Frontal Area (m ²)	Cd	Battery Life (days)
Min. Distance	10	75.98	542.64	91.88	0.0504	0.2150	105
Max Utility	16	76.73	1206.91	805	0.1232	0.2360	920
Min Energy	1	80.41	216.79	157.5	0.0195	0.1410	180

Results

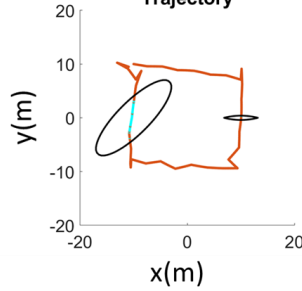


Migration Direction



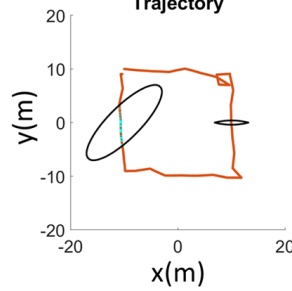
Tag 1

Trajectory



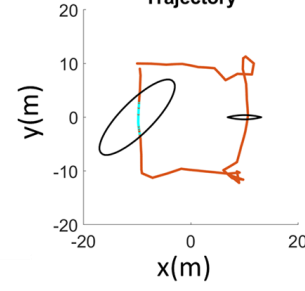
Tag 13

Trajectory



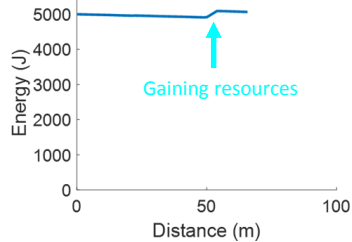
Tag 14

Trajectory

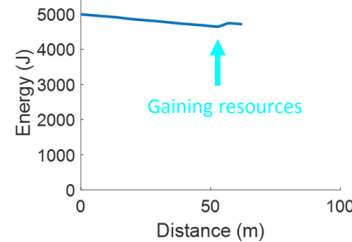


- Losing Energy
- Gaining Resources

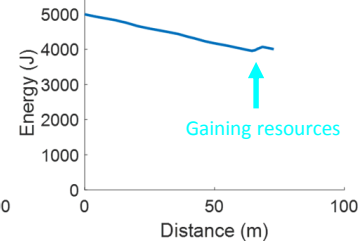
Energy vs. Distance



Energy vs. Distance



Energy vs. Distance





Early results show that tags that have longer battery lives cost turtles more energy
(what one would predict – model validation)

Coupled ABM-design optimization framework works!

- ABMs allow for the study of large spatial scales and long time scales that can't be done with animals
- Enables answering biologically relevant questions, selection of equipment, and better designs

Work presented here can be used as a starting point

- Results will get REALLLY interesting when we allow for the agent to change its path based on its current energy level
 - Allow drag force to influence velocity (currently does not)
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Questions

and, Thank You!





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$$P_{mech} = \vec{F}_d \cdot (s\hat{d} + \vec{v}_{fl})$$

$$|\vec{F}_d| = \frac{1}{2}\rho|\vec{v}_{rel}|^2SC_d$$

$$\vec{F}_d = |\vec{F}_d| \frac{\vec{v}_{rel}}{|\vec{v}_{rel}|}$$



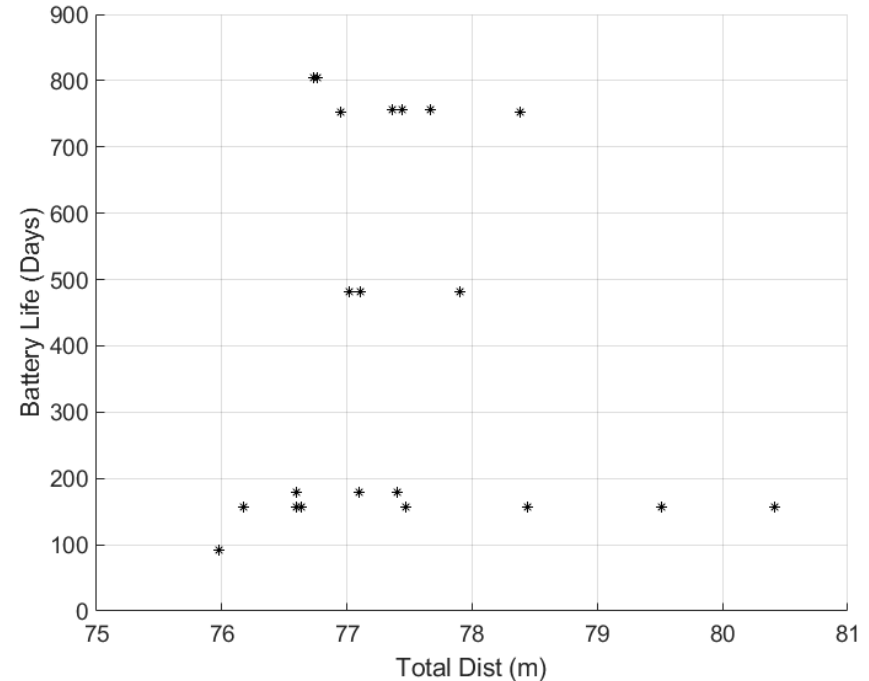
$$E_{k+1} = \begin{cases} E_k - P_{mech}\Delta t & \text{if no resource encountered} \\ E_k - P_{mech}\Delta t + E_{res} & \text{if resource encountered} \end{cases}$$

$$\hat{d} = \frac{\vec{d}}{|\vec{d}|} \quad \text{Function of the sensory environment}$$
$$\vec{d} = \begin{bmatrix} f(\vec{x}_g, \text{parameters}) - f(\vec{x}, \text{parameters}) \\ g(\vec{x}_g, \text{parameters}) - g(\vec{x}, \text{parameters}) \end{bmatrix}$$

Results (Battery Life vs. Distance)



- Agents are taking similar paths, regardless of the tag size and battery life
- However they are consuming more energy using tags with a longer battery life



Results (Battery Life vs. Energy)



- As expected, the agent must consume more energy if carrying a PTT that has a larger battery
- Subsequently implies more drag

