Father and Son Venture into the Unknown

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About the Father

I am a professor in and chair of the math department at Concordia University, St. Paul. I have teaching degree in math secondary education from Concordia University, Nebraska and a Ph.D in mathematics from the University of Nebraska-Lincoln. This is my 20th year in St. Paul.

About the Son

Jack is a junior math major. He is currently applying to summer REU and is a co-captain on our first ever eSports team. His game is Overwatch.

About SCUDEM

SIMIODE Challenge Using Differential Equations Modeling (SCUDEM)

Teams of 3 undergraduate students

Choose from 3 published scenarios

This year was SCUDEM V

Virtual Competition

This was our first foray into the competition

Independent Study

Six upper-level undergraduate math majors (one was Jack)

Objective of the course...DO MATH!

We completed a number of modelling scenarios, some from Simiode and some that I wrote.

Deeper dive into SAGE (open-source computer algebra system) then I give them in other courses.

Learn more data analytics tools.

Prepare for competitions such as SCUDEM

Practice

Problem from 2019 SCUDEM competition

Problem C: Chemical Espionage

Synopsis: Large cabbage white female butterflies use chemical signals to attract mates while the males use chemical signals to dissuade other males. At the same time, parasitic wasps can detect these signals and lays eggs amongst the butterfly eggs.

Other Resources

www.simiode.org

SIMIODE

- Participated in two Simiode conferences (MINDE and DEMARC) in the past and colleagues spoke highly about the student experience

- Past problems/solutions

- Student video giving advice to participants

- Scoring Rubric (next slide)

Scoring Rubric

Well-Executed

- Applies a **strategy** that makes sense for the given question
- Applies appropriate mathematical concepts and processes
- Does not offer superfluous material
- Technology is used appropriately
- Work is logical and includes a reality chec of the final answer

Well Communicated

- **Readable:** Work *stands alone* (retains context) and is neat and professional
- **Organized:** Provides a *clear logical* flow
- Provides detail, rationale, explanation
- Work is free from grammatical errors
- Mathematical composition, terminology, and notation is correct
- Results and/or conclusions are clear

Essentially Correct

- **Precision:** Performs mathematical operations correctly
- Makes and uses assumptions clearly
- Uses an appropriate degree of accuracy
- Draws correct inferences from graphical or numerical data
- Any computational or algebraic errors are trivial and isolated
- Correct units are used

Score Descriptors:

5	4	3	2	1
Excellent	Very Good	Good	Fair	Poor
Well-executed, well-communicated, essentially correct. Offers reflection on model.	Generally well-executed but may have minor communication flaws or some errors. Describes model development.	Adequately executed but with some non-trivial errors or inconsistent communication. Conveys basic idea and rationale for model.	Flawed execution possibly with non-trivial errors or poor communication. Model presentation not clear or conveyed well.	Unsatisfactory execution and/or communication with fundamental errors Lack of clarity in defining terms and explaining model.

Assumptions in Jack's group

1. Wasps are the only predator/hijacking insect interested in the eggs of the butterfly.
2. Butterflies are the only interactive prey that the wasps are interested in.
3. Closed environment, allowing not migration of either species.
4. Continuous growth of butterfly egg population, wasp population, and butterfly population.
5. Both wasp and butterfly population need not worry about starvation or
environmental threats.
6. Wasps need butterfly to reproduce

Modeling Equations

$\mathcal{W}$ = wasp population

$\mathcal{B}$ = butterfly population

ϕ = male butterfly success rate

μ = wasp hijack rate

β = wasp death rate

ρ = death rate of butterflies

$(\phi - \rho) = \alpha$ = rate of change for butterfly population accounting for both death rate and male success rate.
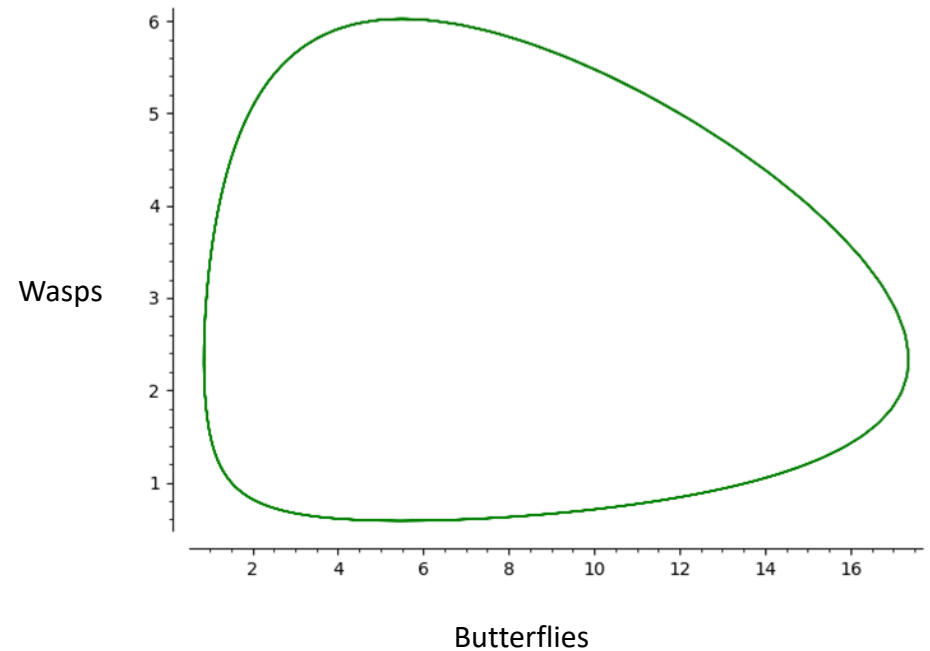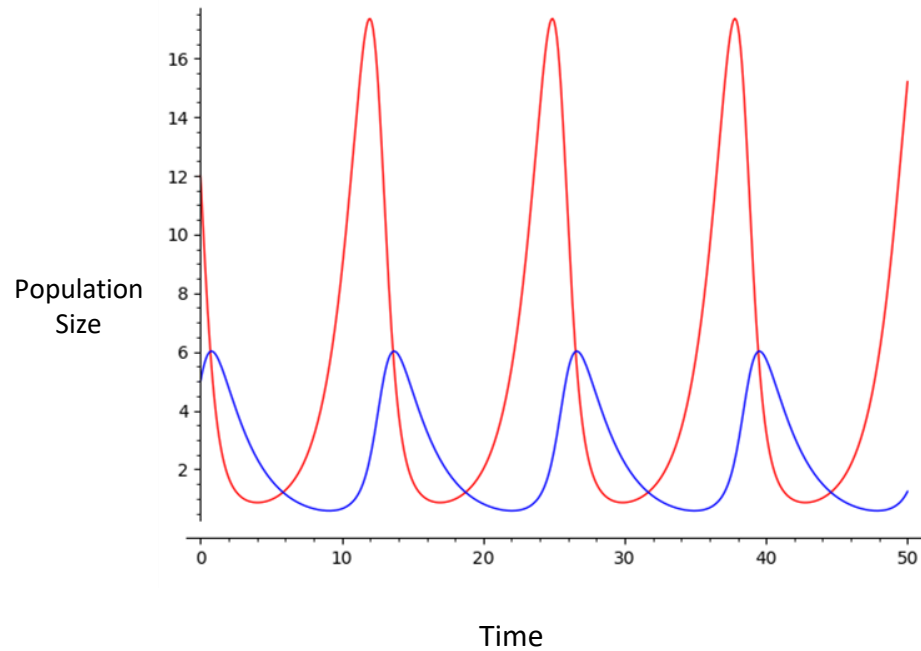
$\mu, \rho, \phi, \alpha, \beta$ are all positive constants.

$$\frac{d\mathcal{W}}{dt} = \mu \mathcal{B} \mathcal{W} - \beta \mathcal{W}$$

$$\frac{d\mathcal{B}}{dt} = \mathcal{B}(\phi - \mu \mathcal{W}) - \rho \mathcal{B} = \mathcal{B}(\phi - \rho) - \mu \mathcal{B} \mathcal{W} = \alpha \mathcal{B} - \mu \mathcal{B} \mathcal{W}$$

Modeling Code

```
1   x,y,t=var('x y t')
2   sol=desolve_system_rk4([0.7*x - 0.3*x*y,0.08*x*y - 0.44*y],[x,y],ics=[0, 12, 5],ivar=t,end_points=50)
3         #Notice the initial conditions (t, x, y), the independent variable, and the ending t value
4   txpoints=[ [i,j] for i, j, k in sol]
5   typoints=[ [i,k] for i, j, k in sol]
6   xypoints=[ [j,k] for i, j, k in sol]
7         #To plot we need to choose which pairs we are interested in
8   tx=list_plot(txpoints, plotjoined=true, color='red')
9   ty=list_plot(typoints, plotjoined=true, color='blue')
10  show(tx+ty)
11        #We can show both plots together
12  list_plot(xypoints, plotjoined=true, color='green')
```

Sage Graphs

Population Size

Time

Wasps

Butterflies

Both of the groups had interesting results and each group had a leader who seemed to be jazzed about the modeling.
Everything seemed to be going great...

What could go wrong?

SCUDEM V - 2020

Problem A: Decay of Oil Agglomerates From The Deepwater Horizon Accident

Synopsis: Studying the breakdown of the oil clumps leftover from the 2010 Deepwater Horizon accident. It turns out exponential decay models do not provide a good fit for the change in overall mass of the clumps. Can a better model be developed?

What didn't work

Many of this group participated in MinneMUDAC, a data analytics competition hosted by MinneAnalytics on the Optum campus in the Fall of 2019.

The off-campus experience, surrounded by hundreds of their peers, was an exciting day. They were hoping for a similar experience.

Unfortunately, MinneMUDAC was cancelled due to Covid. But SCUDEM was virtual!

However, they really missed the excitement of dressing up and the live competition.

Jack's Perspective

- He was interested in working outside the box. He had Excel models that his partners were less than enthusiastic about understanding or participate in generating.

- Once their group finally agreed on the model, they were worn out…

- The video production was more challenging then they expected and disaster ensued.

- Trouble posting video to SCUDEM

How I screwed up

- I teach a combined Differential Equations and Linear Algebra (DELA) course. So time is a premium. Sudents hadn't seen problems that couldn't be solved using our learned methods…they didn't know enough about solving problems numerically.

- They were finishing up their practice presentations as the competition started.

What will be better in the future

- Students really like the idea of travelling…for those that can fit it into their schedules.

- Involve younger students earlier…introduce in math club.

- More numerical analysis.

- Practice making videos!

- It won't be my first rodeo.