SCUDEM 2018 Problem A - Sorting Recyclables

When recycling began in the United States many places required that people separate the different kinds of materials they recycled, and the different materials were collected separately. The initial recycling rates were low, partly due to the inconvenience of having to separate and keep the materials apart. Since that time single stream recycling has become more common, and people can simply place all of their recyclable materials in a single bin. The resulting materials are then sorted at a recycling facility.

Recyclable materials generally go through a number of stages to separate the different materials. One stage is used for the materials that consist of either paper or cardboard materials. These are difficult materials to separate, and a good deal of this material is sorted by hand. The question to explore is whether or not a simple process can be developed that will help separate a large percentage of the materials, specifically paper and cardboard materials.

A simple device will be tested in which the materials will be dropped from a great height, and a fan will blow air across the stream of falling material. Determine the minimal height and wind speed that can be used to separate 30%-40% of the paper that is in the falling column of material. For our purposes you should assume that the distribution of the paper and cardboard items are relatively uniform but make sure your assumptions are explicitly stated. The goal is to establish the feasibility of the general idea before proceeding to a more complex situation.

SCUDEM 2018 Problem A - Sorting Recyclables – Additional Issue

1. In practice there is a difference in the ratios of paper and cardboard between incoming loads. Use your model to predict the differences in percentages that can be accommodated yet still maintain consistency in the sorting results.
2. Different locations have different costs. For example, it costs more to increase the area of a building in an urban area compared to a rural area. Based on the trade offs between height, area, and energy to run the fans, determine the range of costs associated with different configurations given a desired final quality associated with the sorting procedure.
3. Which aspect of your model results in the largest difference in sorting quality if that aspect undergoes a small change. For example, does a small change in the height of the drop make a bigger difference in the final results as compared to a small change in the wind speed associated with the fans?

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SCUDEM 2018 Problem B – Alarm Bells

Prey animals have to strike a balance when deciding whether or not to flee a potential predator. Moving away in a hurry can expend a great deal of energy, and some prey animals only have a limited ability to detect a larger animal's intentions. As an example, this dilemma was explored in a recent paper [1]. The researchers in this particular study examined the response of larval zebra fish and found that both the size of the potential predator and the rate the size changed influenced how the larval fish responded to a potential threat.

We ask that you explore the general phenomenon and develop a system of ordinary differential equations that mimics this behavior. The basic idea is that relatively simple organisms must make complex decisions and do so with the least possible resources. Is it possible for an organism to incorporate a relatively small amount of information, such as the size and he rate of change of the size of a potential threat, and then make this decision based on a simple model of ordinary differential equations? If so, what does your model imply about repeated exposures? Does the frequency of those exposures in a short time have an impact on prey response?

A good starting point for understanding the basic ideas behind these models can be found in a paper by Tyson [2]. The models in this paper demonstrate how a response can be determined from a single input. The question we ask is, "How can two or more inputs be incorporated together to enable a simple organism to decide whether or not to flee?"

References

1. Bhattaacharyya, K., D. L. McLean, and M. A. MacIver. 2017. Visual Threat Assessment and Reticulospinal Encoding of Calibrated Responses in Larval Zebrafish. *Current Biology*. 27(18): 2751-2762. http://dx.doi.org/10.1016/j.cub.2017.08.012. Also see https://www.eurekalert.org/pub_releases/2017-09/nu-net090617.php .

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2. Tyson, J. J., K. C. Chen, and B. Novak. 2003. Sniffers, buzzers, toggles and blinkers: dynamics of regulatory and signaling pathways in the cell. *Current Opinon in Cell Biology*. 15(2): 221-231. https://bioinformatics.cs.vt.edu/~murali/teaching/2003-fall-cs6104/papers/modelling/tyson-current-opinion-cellbio-vol15-2003-sniffers-buzzers-toggles-blinkers.pdf .

Problem B - Alarm Bells - Three Additional Questions

1. Using your model to determine the best strategies that a predator can use to successfully catch a prey animal that uses your model to determine when to flee.
2. Your model should have two criteria that are used to determine when to flee. Determine the trade-offs that result if a prey animal uses your model to determine when to flee. For example, as the parameters in one criteria change, what is the resulting influence of the other criteria?
3. Suppose that a large school of prey animals makes use of your model to determine when to flee. What will happen to the school if the flight response of one of the prey animals is triggered? Will the stimulus of one prey animal fleeing trigger the same response in the other animals? If so how will the trigger spread through the school?
4. Assume that the prey animal has one primary predator. As the predator changes the way it hunts what changes will result in a prey animal that makes use of your model to determine when to flee? Assume that the population of prey animals undergo small changes in the parameters used in your model.

SCUDEM 2018 Problem C - Modeling the Cool Kids

One common stereotype about interactions of students at high school and college is that students self-organize into different social groups or cliques. The way different groups of people come together and form social bonds is a well-documented phenomena and not just an old Hollywood trope. One aspect of this phenomenon that is not well understood is how the groups change over time. As an example, a group of researchers recently found that solely examining academic performance was a good predictor of how close people could be tied together [1]. They also found that the resulting networks that bind people can reorganize in time, based on a small number of factors.

The question to explore is how can the dynamics of social interactions and grouping be modeled and examined in time. Can an ODE model that only makes use of a very small number of social factors mimic complex group dynamics that change in time? What does your model predict for how quickly groups can form and change? What will happen in the long run? Finally, what happens as the number of groups increases? For example, will just having two groups be more stable than having three or more groups that interact?

References

1. Smirnov, Ivan and Stefan Thurner. 2017. Formation of homophily in academic performance: Students change their friends rather than performance. Published: August 30, 2017. https://doi.org/10.1371/journal.pone.0183473 .

Problem C – CoolKids - Three Additional Questions

1. Show how to extend your model to include more groups or cliques. What happens as the potential number of groups gets large?
2. How can your model be extended or changed to examine the dynamics of how people identify with political parties? (Your model will have to include the option to not be part of any group or party.) How do the dynamics change in this new situation and what changes are necessary to demonstrate cross-over voting?
3. The original model examines what happens in the relatively closed environment of a college or university. How can the model be extended to examine the dynamics of what happens after graduation and people move to different geographic areas. What does the model predict about the differences in group dynamics before social networks were readily available compared to the current environment.