Computational Science vs. Zombies

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Abstract. Computational Science attempts to solve scientific problems through the design and application of mathematical models. Researchers and research teams need domain knowledge, along with skills in computing and, increasingly, data science expertise. We have been working to draw students into STEM, Computational Science and Data Science through our Team Zombie outreach program. The program leads the students through a scenario of a disease outbreak in their local area, which turns out to a potential zombie apocalypse. They become part of Team Zombie, a multi-disciplinary response team that investigates the outbreak; models the spread and potential interventions; works towards cures or vaccines; and provides options for detection and monitoring. Throughout the activities we make reference to real-world situations where the techniques are applied. Our program has engaged students from primary school through to university level, raising awareness of the range of approaches to problem solving through models and simulations. We hope this will inspire students to choose courses and careers in computational and data science.

Keywords: Education · Computational Science · STEM

1 Introduction

Around the world, educators are working to boost student interest in Science, Technology, Engineering and Maths (STEM). According to Scitech, 'As we shift to an information-based, highly connected and technologically advanced society, STEM can empower individuals and communities with the problem-solving capabilities to meet unprecedented economic, social and environmental challenges' [1]. In addition to developing interest in the STEM subjects themselves, we can inspire students by exploring scenarios that require a combination of STEM knowledge and techniques.

Computational and data science provide many vibrant examples of STEM. Combining one or more science disciplines with computer simulations and data analytics can give interactive and realistic experiences. A key requirement for outreach activities is to be able to easily explain the context and be inclusive of a wide range of ages and backgrounds. To give better reuse and flexibility, we also look to allow for hiding or revealing details, and moving through a range of

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models/solutions. An important point to get across is that we are working with models, which will always be wrong [2]. Inspired by The Shodor Foundation's [3] resources for mathematics and science education through the application of modeling and simulation technologies, we have previously developed outreach activities exploring supercomputing and simulation [4]. In this paper we discuss the development and results of a story/scenario-based approach where various techniques are applied through the investigation of a zombie apocalypse.

2 Approach

The initial simulation that inspired this work was an assignment set in Fundamentals of Programming, a Python programming course developed for Science and Engineering students at Curtin University [5]. The assignment gave students a simple model of disease spreading through a population, which they then had to extend to incorporate barriers, immunity/recovery and airports. Discussions around the assignment often referred to it as modelling the zombie apocalypse. The additional engagement this elicited was a sign of the potential of the scenario for outreach purposes.

To give authenticity to the resources, we considered real epidemic monitoring and policy. Table 1 provides an example of the steps taken when investigating a disease outbreak. Our scenario begins by going through the steps required to identify and characterise a disease outbreak.

Table 1. Epidemiologic steps of an outbreak investigation [7].

Step	Description
1	Prepare for field work
2	Establish the existence of an outbreak
3	Verify the diagnosis
4	Construct a working case definition
5	Find cases systematically and record information
6	Perform descriptive epidemiology
7	Develop hypotheses
8	Evaluate hypotheses epidemiologically
9	As necessary, reconsider, refine, and re-evaluate hypotheses
10	Compare and reconcile with laboratory and/or environmental studies
11	Implement control and prevention measures
12	Initiate or maintain surveillance
13	Communicate findings

Steps 1–4 would be done as preparatory work, looking at health, media and other reports. This is the settling in part of the outreach activity. Once the

zombie diagnosis is established, we need more specific information about the type of zombie outbreak we're looking at (step 5–6):

Depending on the time available, we might have an activity around researching the various types of zombies in movies and literature. From our research, these are some of the known Zombie types (transmission and behaviour):

1. Viral: An airborne virus infects the entire population. When people die, they re-animate four hours later as zombies. These zombies are gradually decomposing. They can be killed by destroying their brain. (Ref: Walking Dead)
2. Contact+Hoarding: Hoard zombies are attracted to sound, and speed up when moving towards noise. Contact from zombie to innocent bystander will turn said bystander into a zombie. Conversion takes twelve seconds. (Ref: World War Z)
3. Plant-based: A plant releases spores that turn people into zombies and hosts of the infection. The zombies transfer the spores to others. Animals can also be infected. (Ref: Last of Us)
4. Smart Zombies: Most zombies are mindless, but some can open doors and may be able to catch planes etc. [6]

With the infection information, and an understanding of the type of zombie we are dealing with, it's time to develop and validate models of the outbreak (steps 7–10). These can extend on the models used in the assignment, described earlier. Steps 11–12 look at the response and monitoring of the situation, while the final step looks at communicating the plans and progress of the response. The steps may be carried out in parallel, and may have feedback loops to update and reassess based on additional information throughout the investigation [7].

The context for the outreach tasks is given to the students by memos, briefings and/or developed websites. After consideration of the various computational tools that could be developed for battling the Zombie Apocalypse, we focused on three key demonstrations:

– Zombie Outbreak – modelling the spread of the disease
– Zombie Detector – application of computer vision and machine learning to automatically identify zombies
– Zombie Vaccine – once a potential vaccine has been identified and developed, modelling its dosage and distribution

We will now describe the approach and implementation for each of the demonstrations.

2.1 Modelling the Zombie Outbreak

As the purpose of the model is to communicate the concepts around the spread of disease, we focused on the visual and interactive elements of the implementation. The Python simulation begins with a healthy population in a 2D grid. We use the PyGame package to provide an interactive interface where the user can click on individuals to infect them. The disease spreads via a set probability of infecting

```
for row in range(NUM_ROWS):
    for col in range(NUM_COLS):
        # if person is infected, randomly infect surrounding people
        if(infected[row, col]):
            # indices of people surrounding person
            for index in [[-1,-1],[0,-1],[1,-1],[0,-1],[0,1],[-1,1],[-1,0],[-1,1]]:
                inf_row = row + index[0]
                inf_col = col + index[1]
                # ensure not out of boundary
                if(0 <= inf_row < 64 and 0 <= inf_col < 64):
                    if(bridges[inf_row, inf_col]):
                        print("trying to infect bridge")
                    # ensure not infecting water
                    if(not water[inf_row, inf_col]):
                        if(random() < infectability):
                            infect_person[inf_row, inf_col] = 1

# infect assigned grids
for row in range(NUM_ROWS):
    for col in range(NUM_COLS):
        if(infect_person[row,col] and not immune[row,col]):
            assign(row, col, "infected")
```

Fig. 1. Python code for modelling the spread of disease

a cell's neighbours in a Moore neighbourhood (eight directions). The main loop of the program is shown in Fig. 1.

Healthy and infected cells/individuals are indicated by colour (green/red in Fig. 2). A third option is a proportion of the population having immunity (yellow) which contains the spread of disease. Users can also enter a value to speed up the simulation. Possibly the most compelling part of the application is the underlying map of Perth, which localises the scenario and caused much excitement. Also included are natural and man-made barriers such as the river/ocean and bridges. Users can click on the bridges to break them down, allowing for isolation of the infected population.

2.2 Detecting Zombies

An important step in controlling a disease outbreak is the detection of infected people, preferably using a remote, automated system. When discussing zombies, a range of potential traits were considered:

- Speed of movement - slowness, gait
- Intelligence, or lack of it
- Odour - decomposing flesh
- Temperature - using thermal images
- Appearance - e.g. missing limbs, expression

Although temperature may have been the preferred approach, we chose to work with appearance as it would be engaging in an interactive display. To show the potential of computer vision, the premise was that zombies could be identified by their facial expression. We found no record of zombies smiling, so this could be a clear visual difference between healthy people and zombies.

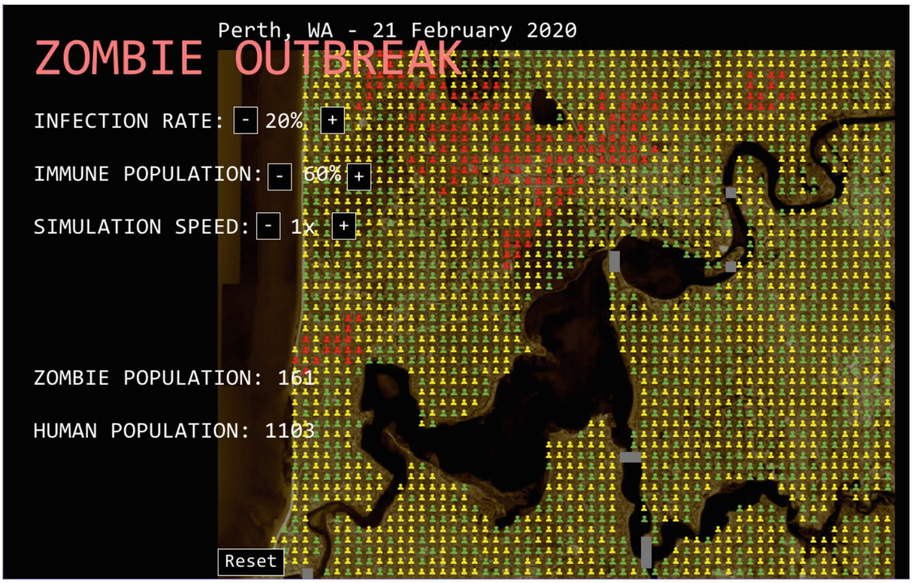

Fig. 2. Zombie Outbreak proved to be engaging and insightful, across all age groups (developed by Cleye Jensen) (Color figure online)

A Python program was developed to work with real-time camera footage to detect faces and flash up a warning if a face is determined to be a zombie (see Fig. 3). Packages used included: sklearn, open cv (cv2), dlib, numpy and csv. The implementation finds a face using HAAR Cascades [8] and puts a bounding box on the face. Then the system identifies 68 facial landmarks, and the positioning of the landmarks is used to determine if the face is human or zombie, based on a training data set.

2.3 Developing a Zombie Vaccine

The third demonstration assumes that a vaccine or medication can be developed to protect healthy humans. Once we have a vaccine, we need to calculate how much of it is required, and how often, for there to be effective protection. With this individual information, we can then consider how many people can be saved, how much medication to produce, and whether there are difficult decision to be made due to limitations in supply.

The demonstration used for communicating these concepts is based on the one-compartment model with repeat dosages described in [9]. This model has been used each semester in Fundamentals of Programming to explore simulations and parameter sweeps. In this case, we limit the interaction to adjusting key parameters to vary the half-life, absorption, dose and interval between doses. The diagram in Fig. 4 show the display of the demonstration code, which we are running in a Jupyter notebook (via Google Colab). In this case, the students see and interact with the code directly.

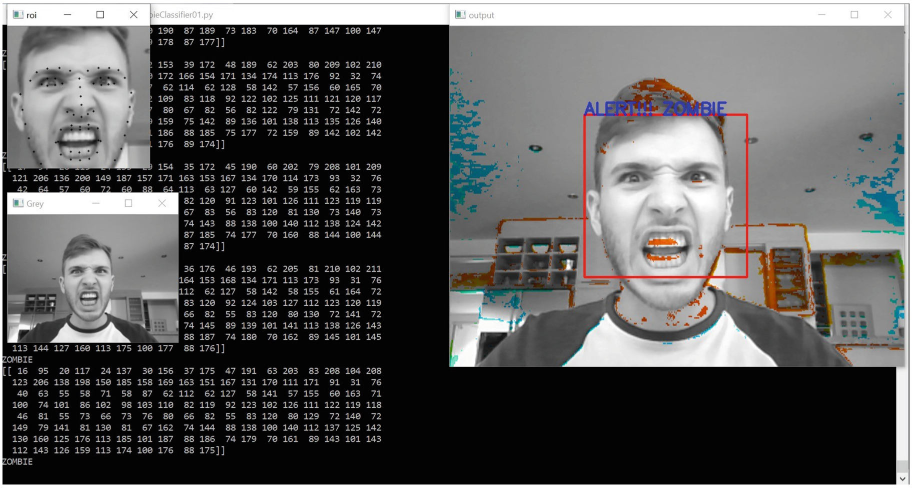

Fig. 3. Visual detection of zombies (developed by Harry Walters)

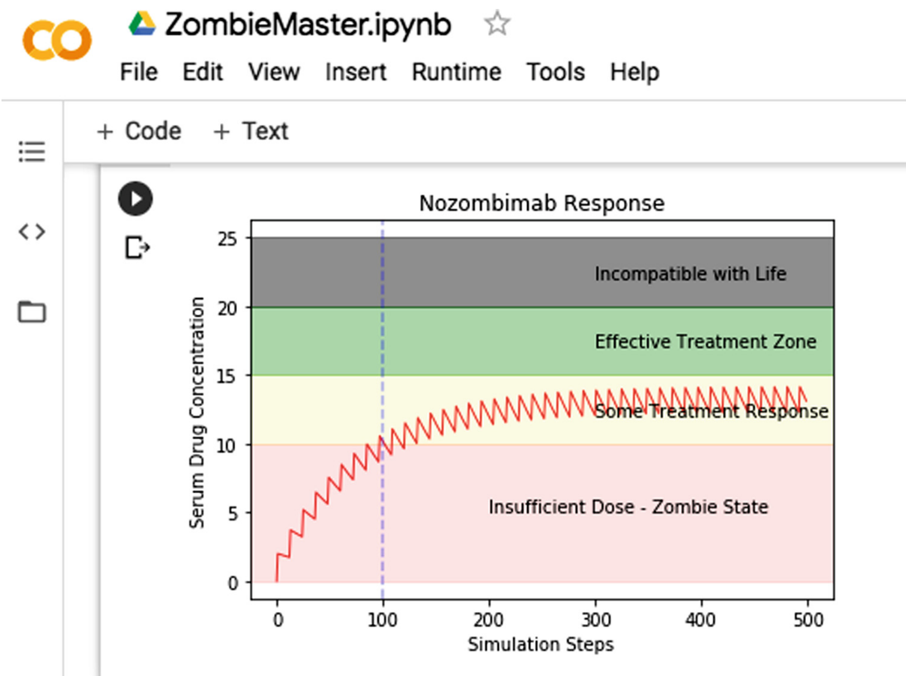

Fig. 4. Drug dosage simulation - this one needs a bit more serum to provide effective treatment (developed by Brodie Sandford, based on [9])

3 Results

The developed materials have been used in two outreach events: a local science festival and a multi-day immersive science experience.

3.1 Perth Science Festival

Fig. 5. Team Zombie booth at Perth Science Festival

This family-friendly event took place at the Claremont Showgrounds on the 24th and 25th August. It is the largest event on the WA National Science Week calendar, with over fifty exhibitors and an attendance of 8,161 people (2018 figures). In pitching for a booth, we needed to give the focus and story for our booth (see Table 2).

Ahead of the event, local media contacted us for an interview to help promote the booth and the science event. The resulting article [10] used the Team Zombie booth as the lead story to promote the Festival. The booth for Team Zombie was a standard 3 × 3 m setup with two tables. We brought multiple computers, explanatory material and zombie decorations (see Fig. 5). It was manned by Computer Science and Data Science students 10am–5pm for two days.

Table 2. Promotional text for Team Zombie booth.

Can you survive a zombie apocalypse? A zombie epidemic is breaking out and we need smart science to save the world as we know it!
Can Artificial Intelligence help us detect zombies? Will your borders hold? Should we shut down the airports? Can immunisation protect the population, or should we focus on finding a cure? How much medicine do we need? How many people can we save?
Work with us as we use computer simulations and Artificial Intelligence to fight the zombies with science!

There was an excellent response from kids, parents and teachers who enjoyed the interactive displays. We were asked about school visits, our website (in progress) and possible mobile phone applications.

In terms of results and effectiveness, the attendees spoke with their feet. We had continual questions and interactions for the full day, often with people waiting to have a turn at the each of the demonstrations. Some children and parents kept coming back to chat, or to explore a different aspect of the simulations. We found they also built on the concepts in our materials, discussing herd immunity and seeing the relevance to current issues such as measles outbreaks and global epidemics.

3.2 Curtin Science Experience

This initiative has been run by Curtin Outreach for over 15 years. The four-day event has a program of science activities for Year 9 and 10 students. The premise is the give students with an interest in science a chance to participate in a range of science activities, with guidance from scientists and engineers who can share their love for their work. We were asked by the organisers to showcase Technology/Data as a link to the State Government's priority areas. We were assigned a two hour timeslot with up to fifty students attending.

The large group was split across two rooms, then into smaller teams or 4–5 to do their investigations. We scheduled the session in a collaborative learning space, giving each group a computer to share, which we prepared by pre-loading all of the software (see Fig. 6).

The lesson plan took students through setting the context; research of zombies; discussion of transmission; interaction with Zombie Outbreak model; discussion of containment strategies; Zombie Detection and Zombie Vaccine development. Google Collab notebooks were used for interacting with the Vaccine code, while the other two demonstrations were set up to run continuously. Our temporary website [11] progressed the scenario through a series of blog posts. Each team had a Google doc to record notes on their investigations.

Table 3. Examples of group investigations.

Group	Excerpt of research
Group A	HOW TO STOP A ZOMBIE APOCALYPSE Responses can be organised into four categories, the scientists say: – Quarantine the infected and develop a vaccine. Quarantines are difficult to maintain and vaccines take time develop – Hide the uninfected. A great plan if you're outnumbered, until the zombies breach your zone and find what the scientists says is a 'perfect environment' for the disease to spread – A selective cull. Effective if precisely orchestrated, but nearly impossible to achieve given that early cases may not show obvious symptoms – Eradicate the infected area. It's guaranteed to end the outbreak, but moral issues remain given the 'heavy losses of uninfected individuals'
Group B	The Generic Zombie – is a person who has been killed and reanimated by a pathogen, often, but not always due to a virus – usually aggressive and curious, but disorientated, and at a loss to fully understand their environment – Their most notable trait is that they kill and eat uninfected humans
Group C	– Conspiracy theories – Government sent zombies to solve overpopulation – Contaminated drinks and food – Team Zombie is actually the one that is infecting everybody to gain publicity and mass chaos
Group D	Possible vaccines: – Inject chocolate into bloodstream. (Permanent solution) – Make chocolate grenades – Make chocolate shooting guns and bullets – Chocolate nuke – Replace every water source with chocolate – Chocolate clothing – Give zombies chocolate so they become happy and not eat us (and then shoot them)

Fig. 6. Team Zombie activities at the Science Experience

A selection of excerpts are reproduced in Table 3. Note that the scenario puts forward chocolate as a potential antidote/vaccine.

Overall the session kept the students engaged and, although the scenario was a bit of fun, it happened to take place when a measles epidemic was causing the deaths of many children in Samoa. By discussing the Samoan outbreak and other epidemics (e.g. Ebola, SARS and now Coronavirus) the students clearly understood the seriousness of such situations and we hope they saw the need for a diverse team from a range of disciplines, using a variety of techniques, to best meet these challenges.

3.3 Media Coverage

Ahead of the Perth Science Festival, local media contacted us for an interview to help promote the booth and the science event. Of over fifty booths at the event, the zombie theme was considered the most exciting to attract visitors. The resulting article [10] used the Team Zombie booth as the headline and lead story to promote the Festival.

During the event, exhibitors for Scitech approached us to provide our 'expert' opinion on how zombies might spread across Australia. This evolved into a feature article for Particle [12], an online magazine producing news, stories and views. Ideas explored in the article included:

– Is it possible to mathematically work out how fast a zombie apocalypse would spread across the world?
– If they only eat brains, would they eventually run out of food?
– As an educated guess, where would it likely start? and being so isolated, does Perth/WA have an advantage?

We worked through some additional models and problems, including consideration of census data (population density) to give a prediction on the hypothetical spread of zombies across Australia. We were informed that the Particle article had strong readership figures and received many queries for more information.

4 Conclusion

We have described an outreach project intended to increase awareness of computational science and the multi-disciplinary teams that are required to address the challenges facing our planet. The project has been able to capture the imagination of students, teachers and parents through interaction with our models and simulations. Lengthy interactions, requests for additional resources and school visits indicate that we have succeeded in engaging our audience. The media interest supports our belief that we have a useful premise and plausible resources. Future work will be to develop an improved online presence and additional resources, including browser and/or app-based simulations, lesson plans and more detailed materials to expand on specific aspects of the scenario.

Acknowledgement. A squad of student volunteers joined Team Zombie to put together outreach materials and interactive displays. Our coding team were:

– Zombie Outbreak – Cleye Jensen
– Zombie Detector – Harry Walters
– Zombie Vaccine – Brodie Sandford

Cleye, Harry, Brodie, Lisa, Caitlyn and Ryan volunteered on the booth at Perth Science Festival. Team Zombie volunteers for the Science Experience were Brodie, Harry, Caitlyn, Nhan, Matthew, Cameron, Jack, Dylan, Brooklyn, Indigo, Bene and Blake.

References

1. Scitech Website: Why STEM Matters. https://www.scitech.org.au/about/why-stem-matters/. Accessed 4 Feb 2020
2. Panoff, B., Shiflet, A.B., Shiflet, G.: Introduction to Computational Thinking, Melbourne, Australia, 2011 (2013). http://messagelab.monash.edu.au/IntroductionToComputationalThinking. Accessed 7 Jan 2013
3. Shodor: SHODOR: A National Resource for Computational Science Education. http://www.shodor.org/. Accessed 4 Feb 2020
4. Maxville, V.: Introducing: computational Science. Proc. Comput. Sci. **18**, 1456–1465 (2013). https://doi.org/10.1016/j.procs.2013.05.313

5. Maxville, V.: Fundamentals of programming for science and engineering. In: 2018 IEEE/ACM 13th International Workshop on Software Engineering for Science (SE4Science), Gothenburg, Sweden, pp. 28–31 (2018)
6. Team Zombie: Zombie Identification, Activity Resources, 23 August 2019
7. CDC: Principles of Epidemiology: Home—Self-Study Course SS1978 (2012). https://www.cdc.gov/csels/dsepd/ss1978/index.html. Accessed 4 Feb 2020
8. Open CV: Face Detection using Haar Cascades. https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_objdetect/py_face_detection/py_face_detection.html. Accessed 4 Feb 2020
9. Shiflet, A.B., Shiflet, G.W.: Introduction to Computational Science: Modeling and Simulation for the Sciences, 2nd edn. Princeton University Press, Princeton (2014). ISBN 0691160716
10. Young, E.: Nerd it up this weekend in Perth zombie apocalypse simulation, In: WA Today, 24 August 2019. https://www.watoday.com.au/national/western-australia/nerd-it-up-this-weekend-in-perth-zombie-apocalypse-simulation-20190823-p52k4e.html. Accessed 4 Feb 2020
11. Team Zombie: Team Zombie website, 11 December 2019. https://valeriemaxville.wixsite.com/zombie. Accessed 4 Feb 2020
12. McGellin, R.: Zombie a-Perth-calypse: a WA survival guide. In: Particle, 19 November 2019. https://particle.scitech.org.au/tech/zombie-a-perth-calypse-a-wa-survival-guide/. Accessed 4 Feb 2020