Simulating the Outbreak of a Zombie-Virus

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Abstract[[1]](#footnote-1)\*

A model MS Word style file is presented here, formatted in a manner similar to the AAAI Latex model style. This file contains MS Word styles with few direct formatting overrides. It is suggested you set your MS Word settings to display the paragraph style (tools / options / view / style area width), and thereby see how you can easily format your paper accordingly. This model style file has been created for use by authors of papers for MAICS 2003. We make no claim that it is acceptable to the AAAI, which is not related to that conference.

## Introduction

The spread of infectious disease among a populace is at least as difficult to model as it is important to understand. Groups like the Center for Disease Control (CDC) actively study and attempt to better understand the spread of pathogens through the populace. The need for data, whether real or simulated, is tremendous.

As it is entirely unethical to stage a trial infectious disease, much of our disease data comes from collected data or models simulating different scenarios. Most infectious disease models make very particular assumptions about the agents of the populace and how they interact. Few models have been proposed that consider non-standard disease conditions. A robust modeling method is required to model the complexities of human contact within a particular environment to model more unusual types of diseases.

Little research has been done to analyze and model the effects of a zombifying-disease. A disease in which infected individuals actively seek healthy individuals in the populace. Given the outward assumption that the disease is not airborne, but transferred through bodily contact, a model that accounts for human contact is necessary.

## Previous Work

While there are different theoretical models for the spread of a zombie-virus, we are considering a virus that is transmitted through bodily fluid via direct contact. Therefore, direct contact with the undead will likely result in some form of inoculation. We will likely use a timer to determine the time from bite to zombification, this could be determined based on the severity of the contact, including the possibility of delayed onset or instantaneous transformation. Research into the transfer of a zombie-like virus has been modeled with potentially disastrous implications for humans. However, with no ground truth, it's very difficult to determine the accuracy of the aforementioned model. By modeling zombie outbreak scenarios with an adapted swarm intelligence approach, a secondary analysis of the dangers can be studied.

## Modeling Human Behavior

Modeling the dynamics of a zombie-virus outbreak requires a significant amount of swarm intelligence. Initially both the human agents as well as the zombies will require a plethora of steering behavior including agent-flocking. Craig Reynolds work on agent steering, *Steering Behavior For Autonomous Characters*, is immediately applicable to modeling a zombie-outbreak (1). Reynolds work is mainly concerned with the development and implementation of steering behaviors via a simple point-mass representation. He shows that many complex activities, especially those of flocking can be easily reduced to much more basic steering behavior. This is needed to formulate the basics of our zombie-virus outbreak simulation.

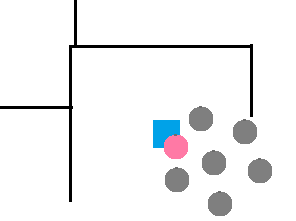
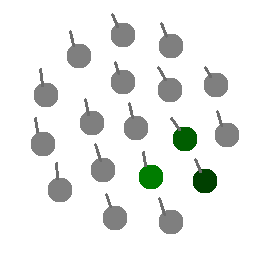
Each agent will need to be able to move and react to its environment. In the case of humans, they will need some form of evasive behavior to avoid zombies. At the same time, the human agents will need to be able to flock with other humans, forming survivor groups trying to escape the zombies. This means that we will need to utilize some form of flocking behavior. This could be achieved with Reynolds' approach to flocking through separation, cohesion, and alignment. A secondary approach to flocking will be addressed later in the proposal.

Humans will also need the basic ability to navigate through their environment. They will need some obstacle avoidance abilities so that they proceed similarly to real humans through their environment. Again, this seems to be covered in Reynolds work, although it seems like there may be a better way of doing some of the necessary calculations to avoid objects. Again we will address this potentially faster and more robust approach to obstacle avoidance and path planning later.

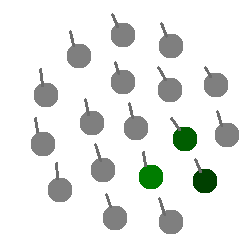
### Modeling Infected Human Behavior

The zombies will need to be able to detect and seek humans in order to sate their endless hunger for brains. Fundamentally speaking the zombies will require basic wandering faculties until they detect a human through their senses. We plan to model both auditory and visual detection in both types of agents.

Their ability to hear will likely be a set radius, where as their vision will be a predefined angle. Representing vision as a narrow cone in a simulated world has proven fairly effective (2). As previously mentioned, upon detecting a human the zombie will enter an excited state due to its immense hunger and attempt to seek out the human. We would like to model hordes of zombies, so when a zombie enters an excited state, it will alert neighboring zombies who will at the least come investigate the loud zombie, if not join in on the human hunt.

A key element in the danger of zombie outbreaks is the panic induced by the zombies. We will model panic behavior in the human agents, likely proportional to the number of zombies in visual our auditory range. Helbing et al. modeled and simulated the dynamical features of escape panic by analyzing human psychological patterns (3). This work could be essential in modeling the panic of the survivors. We will likely branch out from the work in (3) to be based upon the proximity and number of local threats, in our case zombies. This would form a more natural style of panic, in which the panic ebbs and flows according to the current threat of zombies.

### A Secondary Crowd-Dynamics Methodology

This leads us to a secondary potential means of flocking and agent movement. Helbing et al. used *social forces* to successfully model pedestrian dynamics (2). They used a sum of social forces to determine the acceleration of agents in a simulated environment. This approach has proven successful in modeling and simulating standard crowd dynamics. We could use a similar approach to avoid obstacles, flock to other humans, flock and move under panic, and even flee zombies. As determining the vector for acceleration is a straightforward sum of forces, it is quite easy to add in additional factors on the agents' movement. This is where we could use a function dependent on the number and relative proximity of zombies to generate panic behavior.

## Methodology

Each run of the simulation begins with a large number of unarmed humans and a small number of zombies. They are in an environment filled with a random assortment of predefined walls and randomly placed gun caches. As the simulation progresses, zombies hunt and infect humans, while humans try to avoid zombies, pick up guns, and shoot zombies.

We modeled every object in the simulation—humans, zombies, walls and gun caches—as an agent, each with its own set of social forces that it exerts on others. All of the agents have properties such as mass, visual range—that is, angle, distance and line of sight—and velocity. In addition to these, each agent subclass has unique properties.

### Human Agents

In addition to the common properties of agents, humans have personal space, the ability to possess a gun and shoot zombies with it, health, and the ability to incubate the zombie virus if attacked. If other agents are within the human’s visual range, it exerts social forces on them.

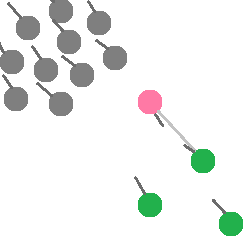
If those agents are walls or gun caches, the forces are simple: humans avoid running into walls and are attracted to gun caches if they are unarmed and the cache is not empty.

Fig: A group of humans encounters a gun cache. When a human acquires a gun, it turns pink.

If the agents are humans or zombies, the social forces are more elaborate. When interacting with other humans, they engage in standard flocking behavior by maintaining cohesion, separation and alignment.

Fig: a flock of humans maintaining separation, cohesion and alignment. Dark green agents are incubating the zombie virus. The lighter the shade, the closer the human is to transformation.

If there are zombies in range, humans behave in one of two ways, depending on whether or not they’re armed. If unarmed, the humans panic and try to escape from the zombies. Humans have a melee attack range, and they can do harm to zombies this way. However, the force to escape is very strong and if a zombie is within this range, the human is probably facing away from it. If humans have guns, their fear is outweighed by a thirst for vengeance. Instead of running, they shoot at them. The accuracy of their shot is sigmoidal and dependent upon their distance from their target. The effect of this is a high chance of killing the zombie outright, a high chance of missing, and a small chance of injuring them. As the zombie gets closer to the human, the chance of a fatal shot goes up and the chance of missing goes down.

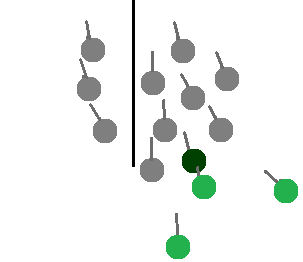
Fig: A flock of humans flees zombies. An armed human shoots a nearby zombie.

If a human is attacked by a zombie, it enters an incubating state. In this state, it continues to appear human to other humans. It loses health until it dies, at which point it becomes a zombie and begins hunting the humans around it.

### Zombie Agents

Zombies are governed by simpler rules than are humans. They have a somewhat larger visual range, but they move much slower. They avoid walls in the same manner, but they ignore gun caches.

Their primary driving force is to hunt humans. If humans are in a zombie’s visual range, it will chase the closest one until it infects the human or the human escapes its visual range. If a human is in a zombie’s attack range, the zombie deals damage to it, bringing it to 90% health and causing it to enter incubation.

Fig: A group of humans fleeing zombies. One human becomes infected. The flock separates when it encounters a wall.

When interacting with other zombies, they maintain separation: they do not flock, but only avoid collisions.

### Walls and Gun Caches

Walls and gun caches are the simplest agents. They do not interact with the other agents per se. Rather, they make calculations that help the mobile agents interact with them. Both calculate whether another agent is within its bounds. Gun caches also keep track of how many guns they contain. Walls keep track of which side of it another agent is on, what its closest point to the agent is, and how far the agent is.

## Conclusion

Our experiments indicate that the human species would likely be wiped out by zombie infection. The capacity for human infection grows significantly when other infected agents seek to spread the pathogen. This can only be successfully combated if the humans are exceedingly well prepared.

Whether through the use of guns or other aggressive means, an immediate effort to destroy the infected individuals is the best survival strategy. If the zombies are allowed to wander the chances of them infecting individuals from new packs increases greatly.

### Impact

### Future Work

The model could easily be extended in a number of areas:

1. Further implementations of weapons, including more significant variation in the range of melee weaponry

2. The modeling of particular guns, yielding different accuracies, rates of fire, and impact

1. The modeling of limited ammunition
2. Requiring human agents to sleep
3. Requiring human agents to eat

### Lists

We have provided styles for two varieties of lists:

1. The “body-list” series is for numbered text paragraphs or sentences such as this one. You can also use it for bulleted lists. The text is right-justified and filled.

2. The “dialog” series, which will be illustrated below, is for indented, ragged-right text, with more space for labeling the items. It is for incorporating data and examples in your text or for lists of very short items. I had been using “dialog” styles for extracts of illustrative dialogue.

3. Item 3 is here merely so you can see examples of the three paragraph styles that comprise the “body-list” series: “body-list1” for the first item (with a little space before), “body-list” for the medial items, and “body-list2” for the final item (with a little space after.).

This paragraph shows you can follow a list style with “body-pp1” if the list is entirely within a paragraph, so the text right after the list is not indented.

The “dialog” series of styles is numbered similarly: “dialog1” for the first item, “dialog” for the medial items, and “dialog2” for the final item. This style has two tabs for inserting the tag, thusly:

--: The first is a right-tab, so the tags are right-justified no matter their widths. Notice that the two bogus tags in this example have different width.

---: Next is a left tab with hanging indent, so the text lines up.

Notice that the body-lists are manually numbered or bulleted in this example. Use a tab after the number. You can use the automatic list option of MS Word if you like, but its behavior drives me nuts.

### Reference Formatting

MAICS does not demand a particular style for bibliographic references. Everybody says they want “APA style” but almost nobody reads the APA style book. You can read the AAAI-inst.ps document for examples of AAAI’s reference style. The references that follow are in my own idiosyncratic style, and I do not suggest that other people follow it.

However I do suggest you follow the basic paragraph and character formatting. The “bib” style for this purpose is unindented with 3 pts leading separating entries. Titles of published volumes, journals, etc. are italicized, not underlined. Titles of papers are in upright type, without quotation marks.

Non-breaking spaces should be used, for example between “vol” and “11” in “vol. 11,” to prevent ugly line breaks. Type ctrl-shift-space to obtain a non-breaking space, or use the insert / symbol / special characters menu. That dash between the numbers in the page range, e.g. “pp. 10–15,” is an en-dash not a hyphen. In MS Word you can type ctrl plus the number pad minus, or use the insert special characters menu.

## Assorted Other Styles

The “text-base” and “para-bae” styles are used for setting the fundamental text parameters (font, line spacing). The other styles are based on these two styles, not on “normal.”

There are assorted other styles in this document that I cannot get rid of. They are left over because I edited this document down from other documents.

## References

1. *Steering behaviors for autonomous characters.* **Reynolds, C W.** 1999, Game Developers Conference, pp. 763-782.

2. *Social Force Model for Pedestrian Dynamics.* **Helbing, D and Molnár, P.** 1995, Phys. Rev., pp. 4282-4286.

3. *Simulating Dynamical Features of Escape Panic.* **Helbing, D., Farkas, I. and Vicsek, T.** 2000, Nature, pp. 487-490.

4. *When zombies attack!: Mathematical modelling of an outbreak of.* **Munz, P, et al.** 2009, Infectious Disease Modelling Research Progress, pp. 133-150.

1. \* If you need to place funding acknowledgements on the first page you can put them here, in a footnote on the abstract. Delete that footnote to delete this section. Ordinarily acknowledgements are in a separate section before the references. [↑](#footnote-ref-1)