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Author(s): Vaibhavi Rangarajan , Karan Murthy
UW NetID: vaibhavi, karan7

Eradicate Cold

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OVERVIEW

The following report is the written component for [Assignment 4] for CSE 415. The chosen wicked problem is eradicating the **common cold.** While the common cold is common indeed, we present the argument for why it is complex, and how to tackle it effectively.

BACKGROUND: THE COMMON COLD

The common cold is a viral infectious disease of the upper respiratory tract that primarily affects the nose.

Causes: Well over 200 virus strains are implicated in the cause of the common cold. the rhinoviruses are the most common, and cause around 50% of the cases.

Symptoms: Signs include coughing, sore throat, runny nose, sneezing, headache, and fever. People usually recover in seven to ten days.

Transmission: The common cold viruses typically require hosts to replicate, and can survive outside the human body for up to 2 days. The methods by which cold spreads include:

- Skin-to-skin contact (handshakes or hugs).
- Saliva (kissing or shared drinks).
- Touching a contaminated surface (blanket or doorknob).
- Airborne respiratory droplets (coughs or sneezes).

Treatment: No cure for the common cold exists, but the symptoms can be treated. Evidence does not support a benefit from cough medicines, but anti-inflammatory medicines might help manage the pain. Research has debunked the effects of Vitamin C supplements and salt water gargles on the common cold.

Prevention: There is no vaccine for the common cold. The primary methods of prevention are hand washing, resting well and staying away from other sick people. Some evidence supports the use of face masks.

How common is it?
The common cold is the most frequent infectious disease in humans. The average adult gets two to four colds a year, while the average child may get six to eight. These infections have been with humanity throughout history.

Effect on Society:
The CDC says 22 million school days are lost each year in the U.S. because of common cold. Some estimates also say that Americans have 1 billion colds a year. The common cold can prove fatal for those with compromised immune systems, or pregnant women and newborn children.

WHY IS ERADICATING THE COMMON COLD A WICKED PROBLEM?

There is no definite formulation of the wicked problem

With over 150 kinds of viruses causing the common cold, there is no comprehensive and singular list of causing organisms for this disease. From a medical point of view, a vaccine against all the relevant viruses is still in the works and far from reality because of the inherent capability of viruses to mutate. Common cold is also highly contagious, and a vaccine will not work unless enough people globally adopt it. This disease is an area of active research in the medical community, and many of the common myths about cold prevention keep getting debunked even to this day. Thus, there is no clear formulation or strategy to ensure that the future of humanity is cold-free.

Wicked problems have no stopping rule.

Eradicating a disease cannot be permanent when a vaccine is not present. With the genetic mutations that occur, and the variety of viruses that cause the disease, there is no scientific consensus on what would be considered a complete eradication. There might be a new mutation or a new virus that causes the exact same symptoms.

Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.

Considering the pervasive nature of this problem, there are no prescribed solutions to overcome the common cold at a large scale or even at the level of a single human. Each of the potential solutions from the medical or political communities will have rolling consequences, which cannot be anticipated or enumerated. Given that the common cold has existed as long as humans have, the question of eradicating the sniffles made an even more daunting task with no definite plan.

PROBLEM PREFORMULATION

Describing the Need

A study by Bramley et.al pinned the monetary c**ost of productivity loss due to common cold at $25 billion a year** out of which $16.6 billion is attributed to on-the-job productivity loss, $8 billion is attributed to absenteeism, and $230 million is attributed to caregiver absenteeism.

Another study had pointed out that the high infectivity of the disease means that it is almost impossible to find humans who have not been exposed to the virus to conduct controlled studies of potential treatments and devise a cure.

Common colds can prove fatal to people with respiratory conditions such as Asthma and COPD. Every human deserves to lead a healthy and fruitful life, according to us.

Thus, we feel that the need for eradicating the common cold is validated by social, psychological, scientific and financial reasons.

Identifying the Resources

There are a multitude of resources from different scientific realms such as virology, psychology, social sciences that were available for research.
The list of relevant literature that helped clarify the problem and aided in its detailed formulation includes:

1. The articles “Why We Don’t Have A Cure For the Common Cold” (Friedman, 2014) “Why can’t we cure the common cold?” (Davison, 2017) give an interesting viewpoint on why common cold is considered incurable at the moment.
2. The articles “Global Handwashing Day Focuses on Need for Universal Hygiene” (Bradley Corporation, 2015) and “The truth about colds” (Landau, 2011) emphasize on the role factors such as adequate sleep, and proper hygiene play in combating cold.
3. The article “Five Surprising Facts About the Common Cold” gives an overview of the necessary precautions one needs to take while interacting with people who have cold.
4. The article on “World Population Growth” (McConnell & Abel) gives a clear overview of the population growth rate.
5. The articles “How Long is the Common Cold Contagious?” (Hamilton, 2017), “Don’t worry, I’m not contagious” (Rohn, 2014), “How Long Is a Cold or Flu Contagious?” give us an estimate of the average time a virus stays inside a host.

POSING THE PROBLEM

Restriction and simplification

The multiple facets that can affect the spread and containment of the common cold span across geographic, political, thermal, social and medical domains.

The **system consists of these agents**:

1. Medical Community - Researchers, Virologists in the race for a vaccine/ cure
2. Governments - The way a government reacts to people and medical research
3. **Humankind** - Humankind is affected as the host for the microbes.
4. Virus - These affect humans and cause the symptoms of sickness.
5. Bio-terrorists- Humans trying to spread deadlier and longer-lasting viral infections.

For us, the **main players in the ecosystem are the humans**. Understanding the intentions and debating if viruses have free will was taken off the table.

The **factors affecting infectivity and severity of Common Cold** are as follows:

1. *Viruses* - They mutate and replicate every day.
2. *Culture* - How often communities gather increases risk of spreading cold
3. *Weather systems* - Temperatures affect the likelihood of cold spreading.
4. **Hygiene**: Many factors such as keeping away from sick people and sleeping well make a difference
5. **Immunity** - Some people are more immune to cold than others.

Here are our **simplifying assumptions:**

1. We consider only the humans as active agents in our formulation.
2. We ignore the mutations in viruses, and are agnostic to the species.
3. We restrict the actions that humans can take as hygiene-related actions only.
4. Hygiene Factors: We chose to model only 2 factors that have been found to correlate with the spread of common cold.

Designing a state representation

Because we chose a human-centered approach that divides the world population as “healthy” or “sick” based on whether they currently are infected by Rhinovirus or not.

Time Frame:
From one state to the subsequent state, we assume that **1 Week** has passed.
We chose this time frame because the duration of common cold typically lasts 1-2 weeks.

Our Model accounts for these phenomena:

1. **Birth** - New healthy specimens are added to the population every week.
2. **Death** - The mortality rate ensures that some sick/healthy humans are removed from the population pool every week.
3. **Washing hands :** Studies have shown that only 5% of the population washes their hands correctly. 50% of all food-borne illnesses occur due to dirty hands. Thus, we

can model the change in risk of getting cold with this habit. We modelled this habit as a possible move for the entire population state (instead of individual)

4. **Sleep:** Those who sleep < 7 hours a day have a three-fold risk of catching a cold than people who sleep >8 hours a night. We modelled this habit as a possible move for the entire population state (instead of individual)

5. **Social interactions:** The average person meets 3 new people a day. We modeled this as a gaussian distribution at an individual level . So each individual will meet a different number of people in a week, drawn from a gaussian process. The more the number of social interactions, the higher the risk of a healthy individual catching a cold.

6. **Recovery period from cold :** Most sick people get healthy after a week, but some continue to be contagious. We chose to randomize the fraction of sick people that recover- ranging from 20% - 50% of the infected population.
7. **Immunological resistance to cold** : We modeled the possibility that even with a high cold risk, some people do not get sick as a bernoulli distribution. Given the risk% of an individual getting a cold, the person gets sick based on a coin toss with a weighted coin based on the risk percent that decides whether or not the person catches a cold.

Designing a set of operators

On average, a human can take only a few precautions
We chose 2 Hygiene Factors : Washing Hands, and Sleeping Well.

If people wash hands, then their probability of avoiding cold increases by 25%.
Additionally if they sleep well, their chances of avoiding cold increases by 5%.
This probability decreases at the same rate if they don't wash their hands or sleep well.

OPERATOR 1 : Wash hands, Sleep well
OPERATOR 2: Wash hands, Don't sleep well
OPERATOR 3: Don't wash hands, Don't sleep well
OPERATOR 4: Don't wash hands, Sleep well

While the number of interactions a person has and immunological response towards cold depends on the individual, we chose to model the hygiene actions as common for the whole population at large. Thus, in a given week, the entire population's risk for cold increases or decreases based on whether they collectively followed good hygiene practices.

If hygiene factors (Washing Hands - YES/NO, Sleep Well- YES/NO) are applied for each person in population of size n, the number of possible moves to create next state becomes 4^n.

By limiting the set of possible moves for the entire population, the branching factor for our problem becomes 4.

Listing constraints and desiderata

We expect that when people follow better hygiene, the chances of the human population being healthy is much higher, and conversely, when poor hygiene habits are followed, the virus should be able to affect more rapidly.

We chose **2 Goal Conditions:**
Either the virus takes over the world, i.e. greater than 90% of the world population gets affected by cold or the virus is under control, i.e less than 10% of the world population is affected by cold.

FORMULAE AND CONSTANTS

1. **Yearly Population Growth Rate**
   1.12%

2. **Predicted Population**
   $N = N_0 * e^{KT}$
   Here N is the predicted population, N_0 is the current population, K is the annual rate of increase of population (1.12%), T is the number of years over which the population growth needs to be measured.

3. **Mortality Rate**
   0.95%

4. **Number of Social Interactions**
   random.gauss(21, 6)

5. **Number of Interaction with virus -infected people**
   Number of Social Interactions * Percentage of affected (sick) people in population

6. **Base Risk Profile of the population**
   50% (Assumption that everyone in the population has a 50% chance of getting sick)

7. **Effect of washing hands on whether the population gets infected**
   25% more chances of getting infected if they don't wash hands and 25% less chances if they do.

8. **Effect of sleeping well on whether the population gets infected**
   5% more chances of getting infected if they don't sleep well and 5% less chances if they do.

9. **Calculated Risk Profile**
   Base Risk Profile + Effect of washing hands + Effect of Sleeping well.

This value can fluctuate between 20% and 80%.

10. **Probability of an individual to recover from cold**
    1 - (Calculated Risk Profile ** Number of Interactions with virus-infected people)

11. **Probability of an individual actually contracting the virus.**
    This is calculated more like a coin toss using random.choices()
    The two outcomes are - individual gets infected by the virus and does not get infected by the virus. The probability of the individual to recover from cold (formula 10) serves as a bias in this case.

CODING UP THE PROBLEM

Specifying in code the state representation, operators, constraints, evaluation criteria, and goal criterion.

Specified in the file Eradicate_Cold.py.

Specifying in code a state visualization method.

We chose to use ASCII art to represent the fraction of the population that is currently sick and healthy.

If appropriate, providing for multiple roles within teams of solvers.

The only roles that we provided for in the code are humans themselves. We did not consider agents such as researchers, doctors, bio-terrorists, governments and the viruses as each one complicates the problem manifold.

Heuristic Function : Manhattan Distance

Since our wicked problem aims to keep the spread of colds under control, we chose a manhattan distance that measures the difference between the percentage of people affected at any given state and the percent of people affected at the goal state. The underlying assumption here is that if the percent of people affected by the common cold is less than 10 percent of the current population, then we have ensured that the spread of colds is under control. The heuristic evaluation function is as follows:

$H_i(s) = Abs(AP_i – AP_g)$
Here $H_i(s)$ is the heuristic function at any state(s) from i = 1 to N,
N is the total number of states in the state space,
$Abs(AP_i – AP_g)$ is the absolute difference (Manhattan Distance) between the percent of population affected at any state AP_i and the percent of population affected at goal state AP_g.

DEMONSTRATING THE PROBLEM FORMULATION

Demonstrate that your problem formulation works by showing some alternative candidate solutions and the derivations (operators and state sequences) that produce them. At the very least, each operator should be demonstrated by giving "before-and-after" state pairs with an explanation of what has changed.

1. **Candidate Solution 1**
   If the percent of affected people is greater than 90, then abort immediately.
   Input:
   Population: 100
   Sick Count: 91
   Output:

```
Welcome to AStar
Initial State:
----------------------------
WORLD POPULATION : 100
SICK count    : 91 (91.00%)
HEALTHY count : 9 (9.00%)

Representative diagram (scaled to 10 humans)
(X = sick O = healthy)

X X X X X X X X X
----------------------------
Cold has taken over the world!
Solution path:
----------------------------
WORLD POPULATION : 100
SICK count    : 91 (91.00%)
HEALTHY count : 9 (9.00%)

Representative diagram (scaled to 10 humans)
(X = sick O = healthy)

X X X X X X X X X
----------------------------

Path length = 0
0 states examined.
```

2. Candidate Solution 2:

Normal flow when the percentage of sick people is less than 90%. The output (virus takes over the world or virus is under control) cannot be predicted because of the random nature of the algorithm.

Input:

Population: 100
Sick Count: 80

```
Welcome to AStar
Initial State:
---------------------------
WORLD POPULATION : 100
SICK count    : 80 (80.00%)
HEALTHY count : 20 (20.00%)

Representative diagram (scaled to 10 humans)
(X = sick O = healthy)

X X X X X X X X 0 0
---------------------------
END: With cold under control (<10%), the World is a better place to live.
*******************************************************************

Solution path:
---------------------------
WORLD POPULATION : 100
SICK count    : 80 (80.00%)
HEALTHY count : 20 (20.00%)

Representative diagram (scaled to 10 humans)
(X = sick O = healthy)

X X X X X X X X 0 0
---------------------------
---------------------------


People washed their hands but did not sleep well
WORLD POPULATION : 101
SICK count    : 40 (39.60%)
HEALTHY count : 61 (60.40%)

Representative diagram (scaled to 10 humans)
(X = sick O = healthy)

X X X X 0 0 0 0 0 0
----------------------------
----------------------------
People neither washed their hands nor slept well
WORLD POPULATION : 102
SICK count    : 20 (19.61%)
HEALTHY count : 82 (80.39%)

Representative diagram (scaled to 10 humans)
(X = sick O = healthy)

X X 0 0 0 0 0 0 0 0
----------------------------
----------------------------
People neither washed their hands nor slept well
WORLD POPULATION : 103
SICK count    : 14 (13.59%)
HEALTHY count : 89 (86.41%)


Representative diagram (scaled to 10 humans)
(X = sick O = healthy)

X X 0 0 0 0 0 0 0 0
----------------------------
----------------------------
People did not wash their hands but slept well
WORLD POPULATION : 104
SICK count    : 8 (7.69%)
HEALTHY count : 96 (92.31%)

Representative diagram (scaled to 10 humans)
(X = sick O = healthy)

X 0 0 0 0 0 0 0 0 0
----------------------------

Path length = 4
4 states examined.
```

RETROSPECTIVE

A) Contributions

Phase	*Task*	*Contributor(s)*
Preformulation	Literature survey on problems	Both
Posing	Defining the model, and equations involved. Identifying the constraints	Both
Coding	State Representation, Can Move, Str, Eq, Copy, Move	Karan
Coding	Operators, Goal Test, Move processes	Vaibhavi
Coding	Debugging and running with BFS	Vaibhavi
Coding	Coding heuristic and running A Star	Karan
Coding	State Visualization	Both
Documenting	Writing Our-Wicked-Problem.pdf	Both

Karan Murthy

I got to learn a lot from this assignment. The model that we created gives importance to personal hygiene but also accounts for other factors that may or may not influence the chances of contracting the virus. Also, thinking about the problem in terms of states and operators was challenging.

Vaibhavi Rangarajan

This was a very challenging assignment, because there were many aspects of the common cold that we had to model. It was really interesting to realize the importance of washing hands and taking care of personal hygiene, that could significantly reduce chances of getting sick. Overall, the model proved to be very optimistic, showing that humanity can recover from even significant colds if enough people take precautions.

REFERENCES

The references have been organized into the sections in which they first appear.

Background

- Introduction - https://en.wikipedia.org/wiki/Common_cold
- Symptoms -https://www.webmd.com/cold-and-flu/cold-guide/understanding-common-cold-basics#1

Why a Wicked Problem

- Difficulties in finding a cure - https://www.theguardian.com/news/2017/oct/06/why-cant-we-cure-the-common-cold
- Current research in domain - http://metro.co.uk/2017/08/02/we-may-finally-have-found-a-cure-for-the-common-cold-6824299/

Preformulation

- Cost of productivity loss - https://www.ncbi.nlm.nih.gov/pubmed/12227674
- Factors affecting common cold - https://www.smithsonianmag.com/science-nature/five-surprising-facts-about-the-common-cold-23293218/

Posing

- Hygiene - https://www.livescience.com/37326-bathroom-hand-washing-habits.html
- Hand washing - https://www.prnewswire.com/news-releases/global-handwashing-day-focuses-on-need-for-universal-hand-hygiene-300159521.html
- Population growth rates - https://en.wikipedia.org/wiki/Population_growth
- Sleep - http://www.cnn.com/2011/HEALTH/02/16/cold.flu.myths/index.html