Assignment 4 Problem Description
CSE 415
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Option A. Wicked Problem
Problem: Fixing World Poverty
Main File: EndPoverty.py

Wicked Problem Justification

1. There is no definitive formulation of a wicked problem.

Fixing world poverty has no definitive formulation. There are numerous perspective of the problem which all warrant their own formulations. For example, one could be of the option that poverty is a population control issue, another could be that poverty is a improper taxation issue.

2. Wicked problems have no stopping rule.

Since more people and capital are being added to the world each year, this problem can never truly be solved. As civilizations/markets/businesses/etc. rise and fall, continuous adjustments or rebalances are necessary to ensure that there are no impoverished people.

3. Solutions to wicked problems are not true-or-false, but good-or-bad.

One can envision many possible routes to solving this problem, and just as easily one can imagine extremely negative or positive reactions to these proposals. The key to solving this problem lies not in finding an allocation of wealth that eliminates poverty, but one that does so fairly.

4. There is no immediate and no ultimate test of a solution to a wicked problem.

Because a potential solution's effectiveness in combatting this problem can only be determined in perpetuity, there is no way to immediately determine if you have arrived at a 'good' solution. Furthermore, as has already been mentioned, this is a problem that may necessitate continued adjustments forever into the future. So a potential solution is really just a plan that gets carried out forever, and may need to be adjusted when new problems/circumstances arise.

5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and-error, every attempt counts significantly.

This is indeed the case in our problem, once wealth has been allocated, it cannot be taken back. This means that the value of sunk costs increases dramatically as you proceed down a solution path.

6. 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.

Because this problem has no solidified rules. The set of possible solutions to the problem is infinite, regardless of the formulation's approach. Furthermore, the set of permissible operations is highly dependent on the formulation's approach.

7. Every wicked problem is essentially unique.

This is indeed the case for poverty. Poverty, a byproduct of a collection of other social and economic issues, has no equal problem in terms of scope and magnitude.

8. Every wicked problem can be considered to be a symptom of another problem.

The existence of poverty is a symptom of unequal wealth allocation, which is a symptom of a capitalist system, which is a symptom of the use of money for obtaining goods etc. One can trace this line of reasoning ad nauseum.

9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.

Poverty can be thought of as symptomatic of several underlying causes, as described above. Some of these causes are inefficient capital allocation, lack of natural resources, poor distribution of job opportunities (or potential employees, a problem potentially exacerbated by national borders), etc. Whichever way you wish to formulate this problem, you will end up tackling it in a completely different way. For example, to combat the aforementioned underlying causes, you might, respectively, attempt to reallocate people's money, move natural resources around or move people to natural resources or increase the efficiency of the use of natural resources, move people to jobs or jobs to people, etc.

10. The planner has no right to be wrong.

Making a mistake in combatting this problem could have extremely detrimental and irreversible impacts on people's lives.

Formulation Description

Basic Initial Formulation

Constants:

In order to define the problem and give our problem states context, we needed to shape the space in which the search was happening. Part of this was defining what it means for an individual to be in poverty, how fast the market grows, etc. Additionally, an initial state was necessary in which there was enough capital for our adjustments to eventually 'solve' poverty. Each of these numbers were tweaked as we developed the problem, and are set as constants in the code. Their descriptions are as follows:

- POVERTY_LEVEL - Threshold each pop member must surpass in goal test
- MIN_WAGE - Smallest wage an individual can start with.
- WAGE_SPREAD - Scale factor for the wage distribution
- INITIAL_POP_SIZE - Number of individuals in the starting population
- INFLATION - Base rate at which wages grow during advancement

- MAX_TAX - Largest tax rate for any bracket
- MIN_TAX - Smallest tax rate for any bracket except 0 (the impoverished, which is fixed at 0%)
- TAX_RET_RATE - Proportion of taxes which are distributed back to the population
- growth_dynamic - Variable rate at which wages can grow
- growth_const - Constant rate at which wages can grow

State:

To track how our problem and adjustments unfold through time, each State object contains two lists. The first is a list of numbers, where the number represents a person's total wage and the index of this value indicates to which person the wage belongs or corresponds. The second is a list of tuples representing tax brackets. These are defined as intervals thusly:

$[\,(c_1,\, r_1),\, (c_2,\, r_2),\, \ldots,\, (INF,\, r_n)\,]$ where if person i has income m : $c_{k-1} < m \leq c_k$ for $k = 1, \ldots, n$ and $c_0 := 0$ they are taxed annually at rate r_k. It should go without saying that both the bracket cutoffs and the rates themselves are all nonnegative.

Operators:

Each transition to a new state can be thought of as one year, and each time a state transition occurs, individuals are taxed at their respective rates and then this total tax sum is distributed evenly among every individual in the population. Additionally, an Inflation/Economic Growth coefficient is used to grow the wage of each individual in our population proportionally to their current wage, and to adjust every tax cutoff accordingly. The available operators are: "Change Tax Rate" and "Change Cutoff". Each of these is available for each tax bracket mentioned above, with the available Δ for "Cutoffs" equal to ± 1000 and the available Δ for "Tax Rates" equal to $\pm\ 0.01\%$. In realistic terms, this means that only one tax bracket can be changed per year, and this change can either take the form of adjusting the cutoff or adjusting the rate by the Δ's mentioned above.

Heuristics:

The simplest heuristic we applied to the problem was called 'h_hamming.' This heuristic counted the number of people below the defined poverty line and adds to this the average difference between adjacent tax rates. The first part of this heuristic obviously penalizes having individuals below the poverty line. The second part of this heuristic slightly penalizes having uneven tax brackets in an effort to create a system that would maximize satisfaction with the system among the populace.

A more successful heuristic added later on was called 'h_avg'. This heuristic takes the average of the difference between a person's wage and the poverty line for all individuals below the poverty line. This heuristic performed much better than the hamming count value because it created greater differences between intermediate states.

Goal:

While there is no explicit goal state, our simulation would return that the goal had successfully been met when there were no individuals left that are below the defined poverty line after taxation and tax reimbursement for that year.

Limitations:

- ❏ Our model is HIGHLY sensitive to initial conditions. This can be characterized as a positive feature (i.e. it is realistic) or a negative one (i.e. certain feasible solutions are never explored). Regardless, this is something we had to consider while exploring how our formulation performed.
- ❏ Additionally, in our initial formulation, money was only ever added to the population. This is fairly unrealistic on both a macro scale (sometimes there are economic collapses or downturns) and on a micro scale (unexpected costs come up in individuals' lives all the time).
- ❏ Because of the scope of this problem we had to severely limit the number of factors in play. These include taxation, subsidies, and wage growth. However, in the real world this problem has to deal with many other factors such as: population growth, economic stability/fluctuation, individual luckiness, savings, NGO aid, and differing standards of living across locales.

Enhancements

In order to tackle some of the limitations identified above, we introduced several refinements over the course of writing our code. While the sensitivity to initial conditions could not be helped, we did add complexity to more accurately model real-world conditions. This sacrificed efficiency (time to find solution) for a more realistic simulation. In fact, the simulation started taking so much time that A* could not find a solution in an appropriate time. So, we had to downgrade our search function to greedy best-first search in order to find an answer.

One enhancement we made was to move taxation and tax return into the goal test method from the advance method. This means that any periods taxation and subsidy does not affect the population's wages in subsequent years, but the current years taxation parameters still affect whether or not the current state is an end to poverty.

Another enhancement we added was to randomly generate the initial population from a Weibull distribution (with shape parameter 0.85 and scale parameter 1.5) that approximated the distribution of incomes in the United States. This creates a more realistic starting point for the simulation and allows for much easier tweaking of population parameters.

A final enhancement was to add wage growth to model a growing economy. This allowed wages to rise of their own volition and provide more money for taxation over time.

Retrospective

(a) what each team member contributed to the partnership's work

Justification and Planning - William & Graham
Formulation v1 & Enhancements - William
Enhancements & More Heuristics - Graham

(b) in each team member's own words, what he or she learned by doing this assignment.

Graham: I learned how to formulate a complex problem in terms of states and operators. Furthermore, I learned a few new Python functions that were useful in this assignment. Some domain specific knowledge that I picked up: how certain progressive taxation systems work and how some people have proposed to eliminate poverty (these informed how we created our problem space).

William: I learned how to represent and think about a wide variety of problems in the operator, state, problem syntax. Breaking complex problems and solutions down into such atomic parts makes them very comprehensible and enjoyable to play with. I encountered a problem space in which A* is not very effective in finding a solution due to the high path length, unlike Greedy Best-first which faces no trouble.