MMC/Mammoth-2024 Problem

To brake or not to brake?

When travelling in urban areas, cars often have to stop at traffic lights and then accelerate again. This results in increased fuel consumption, brake wear, etc.

One way to alleviate this problem is to try to make a “rolling start”: when approaching a traffic light with a prohibitive signal (red light) on, the driver adjusts the speed so that when the permissive signal is on (the traffic light turns green), the stop line is crossed maintaining at least some of the speed (kinetic energy) with which the car approached the light. Obviously, the so-called “greedy” driving algorithm – ‘always drive at the maximum permitted speed on the given stretch of road, and if something prevents you from driving further (in particular, a traffic light), then stop’ – leads to an increase in the number of stops and accelerations.

Develop driving rules that minimize stopping and accelerating at traffic lights.

Tasks:

1. Create an optimal driving rule for the case when the driver approaches a traffic light with a red signal on, there are no other cars ahead (in front of the traffic light), and the traffic light has a countdown indicator for the time remaining until the green light turns on. Note that the driver is a human, not a robot; humans are able to visually estimate distances only approximately.
2. Create an optimal rule for the case similar to Task 1, but without the countdown indicator.
3. Create an optimal rule for the case when one or more vehicles (cars or trucks, motorbikes, buses, etc.) are already in front of the traffic light, the road has a single lane, and overtaking the vehicles in front is impossible. Note that vehicles are generally capable of braking with much greater acceleration than gaining speed (this is more pronounced for cars and less so for trucks and buses; motorbikes are generally capable of even greater acceleration in both directions). Drivers can roughly classify other vehicles in front of them, but do not know their exact parameters.
4. In case of a multi-lane road with the traffic light:
   - 4.1. What is the optimal algorithm for driving a car approaching a traffic light when all drivers stick to the selfish “everyone for him- or herself” rule (thus minimizing only their own losses)?
   - 4.2. Does the optimal algorithm change if the drivers try to minimize the collective losses (or, equivalently, the average expected losses per driver)? Would it be beneficial to have a rule that requires leaving one or more lanes free before a red light, so that at least some of the drivers approaching the traffic light later could make a "rolling start"?
5. Can you suggest any improvements to the functionality of existing traffic lights to facilitate the implementation of the optimal driving algorithms you have proposed? The general scheme of switching between permissive and prohibitive signals (which controls the intersecting flows of vehicles) remains unchanged. The improvements in functionality affect what happens *before* the traffic light and can include

changes in visualization, additional signals, additional sensors and surveillance systems, additional control units (including those based on "artificial intelligence").

In all cases, assume that the driver is an average person, with ordinary abilities to perceive and evaluate the world around them, without superpowers such as instant complex mental mathematical calculations.

Your rationale for optimal rules can use arbitrarily complex mathematical models that give "mathematically precise" answers. However, it is highly desirable that the practical formulation of your optimal algorithms be quite simple.

Keep in mind that fairly experienced drivers actually have an instinctive feel for many quantitative parameters of vehicle motion, although they cannot express them "in numbers". For example, drivers often sense well a linear quantity such as the "normal car-to-car distance", which corresponds to the distance traveled by a car in ≈2 seconds *at the current speed*.

Assume that the driver can quite accurately set any "force" (i.e. acceleration) of gaining speed and braking from zero to a certain maximum determined by the design of the car (engine power, "strength" of the brakes, car mass, etc.).

Requirements:

A. The paper should explicitly identify the sections or passages that contain the answers to tasks 1-5. For example, you may write "(Task 4.1)" at the end of the title of the section with an answer to this task.

B. The paper should be no more than 15 A4 pages, font 12pt, line spacing at least 1.5, standard "medium" margins. The reference list and appendices are not included in the page count, but they cannot contain information critical for understanding and evaluation of your paper. Read the full requirements in the Mammoth-2024 Rules!

C. At the end of the paper, there should be a paragraph titled 'Use of Artificial Intelligence (AI).' It should state whether you have used AI in your research or writing the paper. The use of AI is not encouraged, but it is not prohibited either. If AI was used, a separate appendix to the paper should include the following information: what AI tools were used and for what purpose; what AI query strings were used; and how the results of the AI were checked (because AI can "hallucinate").