The development of meshless Lattice Boltzmann Method - tailored streaming schemes, boundary conditions, and discretization strategies.

What do underground water reservoirs, a supersonic airplane, and a blood test device have in common? Although they vary from each other in many aspects, from their size to their utility for humans, they all feature some kind of fluid flow - water, air, or blood. To study and design them, scientists and engineers must investigate those flows very closely, which is usually possible only through performing computer simulations. Computational fluid dynamics (CFD) is a branch of science that provides them with tools to answer questions like: what will be the level of underground waters beneath a newly built estate, how much fuel will an aircraft burn on its cruise, or how quick and reliable will a blood test performed with self-monitoring kit be. You can compare CFD methods to a set of hammers, screwdrivers, and pliers present in every mechanical workshop, only the purpose of those tools is different.

CFD methods are nowadays used in more and more situations where they are expected to be not only accurate, but also robust, and efficient. This motivates the constant improvement of algorithms in the field of CFD. After all, it is much better to use a cordless drill, than to strain your arms with an old screwdriver. One such handy tool of CFD is the lattice Boltzmann method (LBM). It performs great in terms of speed of calculations, straightforward digitization of complex geometries where the flow takes place, and efforts are put even to adapt it to quantum computing. Surely, the science has a versatile, fast-working drill with a collection of bits to be applied to various kinds of screws. However, in some situations, the drill might turn out to be too large or too heavy to be used easily. It is the same with CFD tools, and LBM is no exception. The amount of calculations it performs to achieve a given goal can sometimes be reduced, and accuracy increased, such that it works quicker, more feasibly, and uses less resources, like electricity. This gives rise to a variation of this method called meshless LBM (MLBM). It is like an upgraded version of your drill, more lightweight and energy-efficient than the basic design. Appealing as it sounds, the new drill is still in the prototype stage, and many questions need to be answered before it can be put on a store shelf.

This project aims to investigate MLBM fundamentally. We will try to explore its features that are important from the physical and computational point of view, as well as compare it with the standard LBM. We will look at the constituents of the new drill, the way they are all connected, and reason how and when it can do its job better than the standard design. If possible, we will suggest improvements to it. Once this is done, we will apply it to simple tasks, like dismantling a shelf in the kitchen to make sure it works properly. Finally, we will choose more demanding setups, like fixing a car riding a bumpy road, and will make a comparison between the original and the new design. Once the tests are finished and their results properly studied, we will gain more fundamental knowledge about MLBM, a premise for its further usage and development.

The project's outcome will benefit several fields of science and engineering. The designers of our cars, or those studying climate change, will gain a new simulation tool to address their questions faster, more accurately, and easily. From an everyday life perspective, this means that goods and services that have to do with the flow of air or water - like airplane flights - will become cheaper, and their quality will improve. In other words, mending your equipment in a CFD workshop will be less of a problem!