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On The Democratization of the Fluid Flow Simulation

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Abstract **-** In this paper, we aim to introduce the web-based application called *dynairix.* Dynairix is a free online tool developed by our team to make the invisible part of pandemics and epidemics visible to the general public. Having a strong background in the field of Computational Fluid Dynamics (CFD), our team has been using it so far primarily in the development of simulation solutions for the automotive production. Now we want apply this know-how in new areas too. The core of *dynairix* is based on quasi steady CFD results using lattice Boltzmann method (LBM) coupled (one-way) with the Lagrangian particles tracking method. Using this methodology, our tool calculates the dynamic risk factor and shows the ventilation system and its effects in closed environments. This is something especially useful during any epidemics where viruses are transmitted by aerosols. The calculations are based on the real physics of the simulations of various scenarios. They show that good a ventilation system during pandemics and epidemics can not only be useful but rather extremely beneficial.

Keywords**:** CFD, LBM, Lagrangian, Risk Factor, Pandemics and Epidemics, Aerosols

1. Introduction

In the past, society and human life in general has been affected by various kinds of epidemics, such as the plague, cholera, flu, severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV). In some cases, such epidemics even became pandemics. Since 2019, the world has been struck by a new coronavirus disease (COVID-19) pandemic [1], with its multiple variants, like delta and omicron. As we know by now, this virus affects the human organism at various levels [2]. It afflicts the lungs and even affects our nervous system [3]. Different methods such as wearing masks and vaccinations [4] have been recommended by various organizations, research- and scientific centres to prevent the spread of the virus. Wearing masks is continuously investigated to demonstrate the effect of how aerosols and droplets travel in person-to-person transmission [5]. In addition, different tools and methods are being developed to show the transmission of the virus, the risks of standing in an infected environment and the effect of the ventilation system on the transmission [3], [6]. However, despite all these efforts, there is one area still largely omitted. So far, only limited attention has been paid to a free online tool which uses CFD simulations to make the invisible part of the risks and transmissions of the virus visible to everyone. With the help of a similar tool, our society could execute the fluid flow simulations without any thorough CFD experience, and therefore also understand the potential risk of pandemics better.

Improving CFD simulation technology, especially particles-based methods like LBM in the recent years, has helped researchers to provide fast and accurate results [7]. Coupling the LBM and Lagrangian particle tracking methods [8] could be used to simulate aerosol transmissions during pandemics and epidemics. In this paper, an online web-based tool is introduced. It couples two of the in-house developed solvers of ESS (Engineering Software Steyr GmbH) - LBM and Lagrangian – with an aim to track aerosols and calculate the risk factor in closed environments. During the COVID-19 pandemic the entire school community has always been worried when it came to the discussion over reopening schools. Therefore, a classroom was chosen as the environment of the *dynairix* application.

2. Pre-processing and Simulation

To run the CFD simulation using the ESS LBM solver, input files need to be provided in "stl" formats. The input files include solid objects and fluid domains in 3-d format, source (inlet) and sink (outlet) objects in 2-d format (surface body). With this, we can define the boundary conditions for our CFD simulation. Particles can be generated automatically with the use of ESS particle generator. After obtaining the quasi-steady results with the ESS´ LBM solver, a velocity field is used and read by ESS´ Lagrangian solver, coupled in one way to calculate the drag force and to find the trajectory of the particles. Lagrangian particles that are generated during the exhalation of the manikins stick to the solid objects and remain there for longer periods of time. Similarly, they can be used for the purpose of risk factor calculation for each individual manikin inside the classroom.

2.1. CAD model and boundary conditions

Figure 1 shows a classroom model with dimensions 8m*7m*3m, in x, z, and y directions, respectively. The classroom has two windows, a door and a fan, which are used as sink and source boundary conditions by considering relevant scenarios. When the fan is on, it is considered as a source boundary condition, and the opened door, or the window, is considered as sink boundary condition. In another situation, the fan is off, the door is closed and one or more windows are opened. In this case, the windows are considered as sink boundary condition. Nevertheless, the windows are always considered as source boundary condition, and the opened door as sink boundary condition.

In total, 16 different scenarios, which are shown in figure 2, can be run using the ESS LBM solver to produce the quasi-steady results for the ESS Lagrangian solver where manikins with source boundary conditions are added to the pre calculated velocity field for online simulation. In figure 2, source and sink boundary conditions are shown with green and red arrows, respectively.

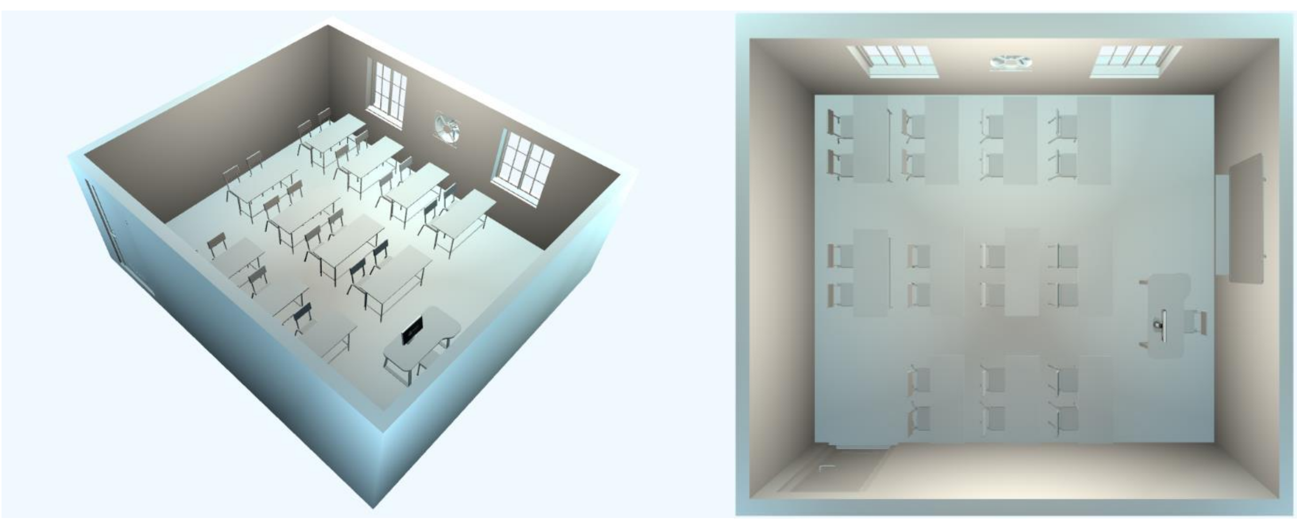

Fig. 1: Solid objects for LBM simulation.

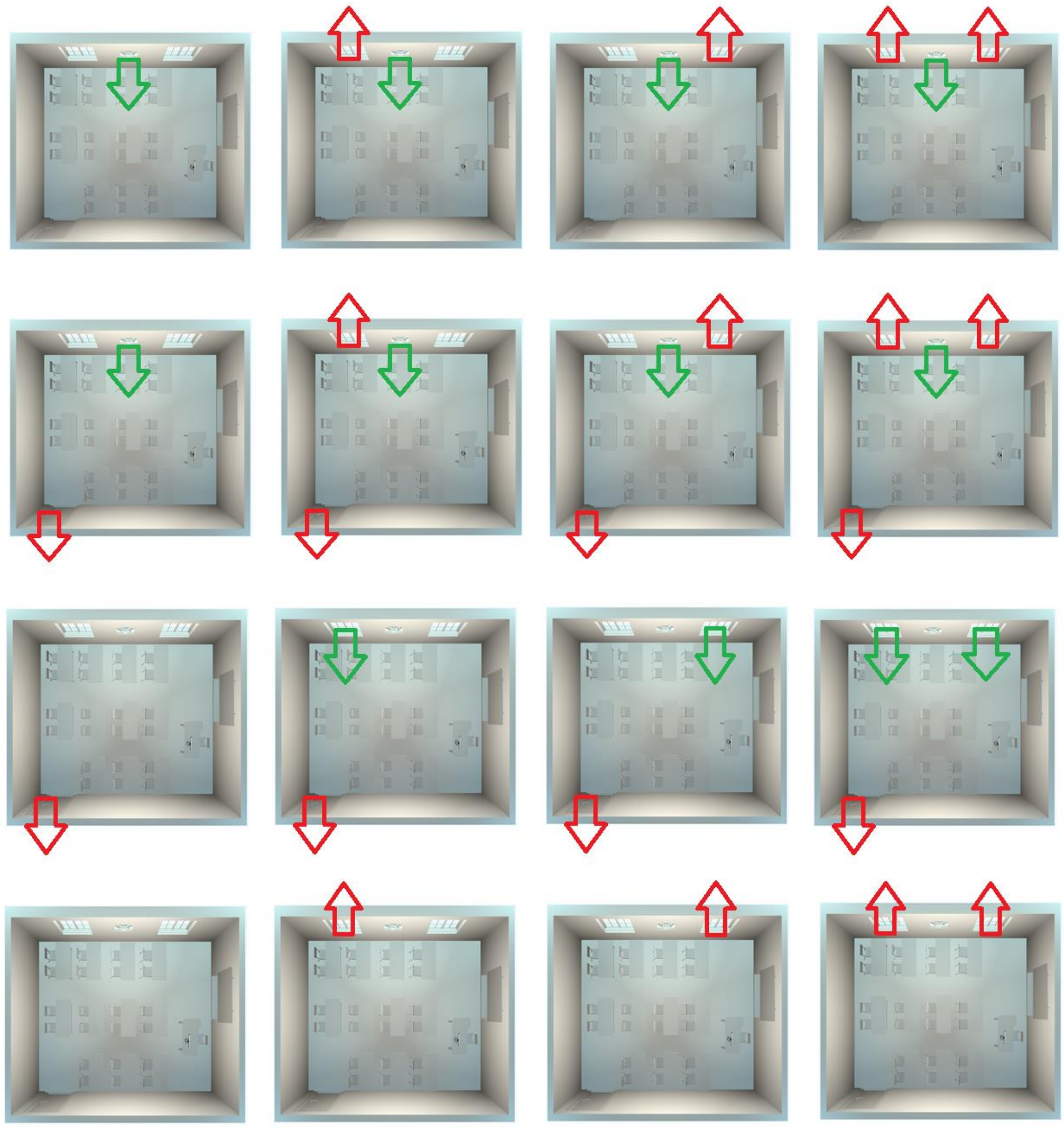

Fig. 2: Boundary conditions and different scenarios, source and sink boundary conditions are green and red arrows, respectively.

2.2. LBM set up and simulation

The LBM simulation is executed for 500 seconds to reach the quasi-steady results. The cascaded or central-moment-based lattice Boltzmann method (CLBM) [9] is applied to simulate the flow field. Fluid property is considered as air at 25 °C.

17,463,904 particles are generated using the in-house code of the ESS particle generator. Simulations are being run on 2 GPUs. A wall time of each simulation according to different scenarios is between 2-10 minutes. When the fan is on, the source boundary condition of the fan is set to 0.6m/s. When one of the windows is considered as source boundary condition, a velocity equal to 0.1m/s is applied.

2.3. Online one way coupled Lagrangian and LBM

The Lagrangian particle tracking method is used to calculate the individual trajectories of the dispersed particle phase [8]. The LBM velocity field is used and read at each particle location. Then, this information is applied for calculation of the drag force. Finally, the force is integrated in time to obtain the new velocity at each time step. Such simulation can be executed online using the online tool *dynairix*.

Risk value is calculated based on the particles that reach each of the manikins, coming from the infected one (particle injector source). The particles that reach solid objects stick to those.

3. Results

To evaluate the risk value, a simple case setup is performed with closed environment scenarios where all windows and doors are closed and the fan is off. Two manikins are positioned in the distance of almost 1.5 meter from each other, face to face. One of the manikins is selected as the infected one. The online simulation is performed for 20 minutes. The results of the simulation show a healthy manikin is exposed to a 100% risk of infection after 20 minutes. Figure 4 shows the risk value increase with the time.

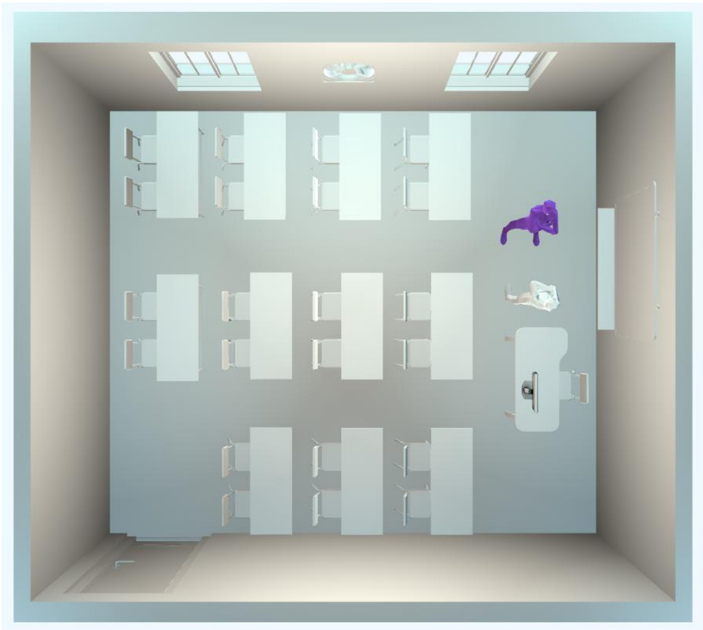

Fig. 3: Case setup for a risk value evaluation. Purple manikin is considered as the infected one.

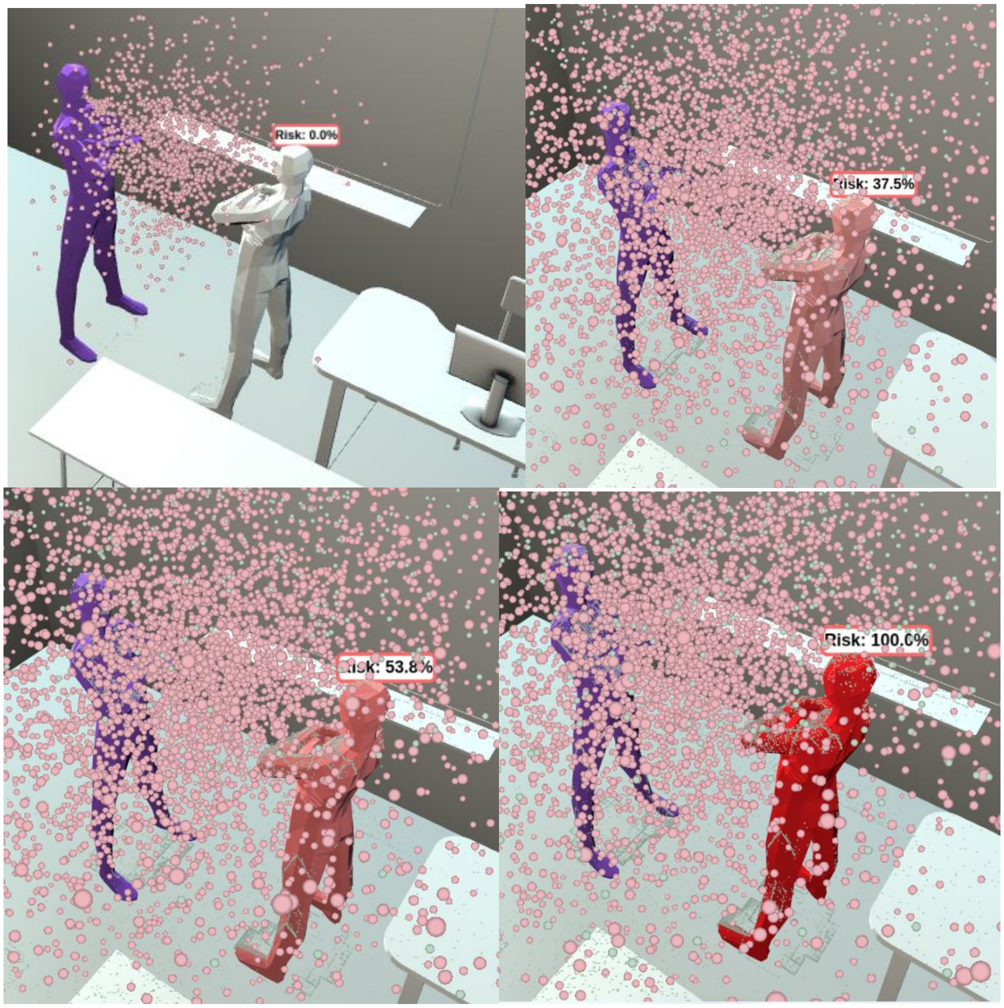

Fig. 4: Online risk factor calculation based on number of particles reach to manikin simulation times from left top corner to right bottom corner are 1s, 450s, 800s, and 1200s which has risk value 0%, 37.5%, 53.8%, 100% respectively.

4. Conclusion

Dynairix, the online web based free application is developed to *democratize* fluid flow simulation. The risk value is calculated based on real physics. This makes the invisible part of pandemics and epidemics visible to society, in order to better protect themselvse. In the future more environments will be added.

Acknowledgements

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