COMPUTATIONAL MODELLING OF SPEECH-DRIVEN AIRBORNE-VIRUS TRANSMISSION

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Abstract

This preprint article summarises our computational virus-transmission modelling of someone talking who is emitting viral-laden bioaerosols, while another person is inadvertently breathing this virus thru their nose while listening. Select preliminary computational results are also presented, along with some supporting validation & verification details. We envision our freely-available model as having the potential to accelerate efficacy of innovative health interventions that target airborne-virus transmission reduction.

Introduction

Very significant lack of health equity for people from 'developing nations' currently exists. We tentatively propose protection against viruses & disease can be increased for such groups of people by designing better 'personal protective equipment'.

Particular groups within the scientific community questioned the real motivations of pharmaceutical companies [1], as their COVID-19 vaccines went mostly to the highest 'bidders', leaving developing countries mostly last-in-line.

Such vaccine access affairs is supposed to be dealt with via the COVAX mechanism, yet comparison of numerous statistics of developing and developed nations [2] indicate COVAX currently fails and needs significant improvement to approach being anywhere close to being equitable.

Meanwhile, the transmission of virus-laden airborne particles (bioaerosols) are a potential way to spread some diseases, while particular diseases are considered by the World Health Organization as especially concerning to humanity at present [3].

These aspects indicate if the next pandemic is more severe than COVID, & occurs relatively soon, developing countries could face greater deaths, even more than their over-represented fatalities endured previously.

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However, collaborative effort to promote a more-equitable future pandemic response has been started [4]. Outside of this context, other research groups have made their software-based platform available for everyone else to exploit [6].

Some research groups are even suggesting mitigating virus transmission using novel methods, such as non-pharmaceutical interventions [5]. We support such upstream approaches, as we have some preliminary research indicating greater effectiveness of Personal Protective Equipment against bioaerosols can be achieved (under simplified and perhaps idealised conditions) by changing their shape [7].

Method

We leverage and develop the freely-available *OpenFOAM* software, while increasing our confidence our computational modelling is adequate via supplementary investigations.

Modelling approach

We leverage the freely-available (open-source) 'computational fluid dynamics' software package OpenFOAM and associated prerequisite meshing software *cfMesh* & *Gmsh*. At a higher level, modelling of the turbulent airflow is done using Large Eddy Simulation, with the modelling of the bioaerosols via Discrete Element Method, while the velocity out of the person's mouth is modelled using a novel (custom-developed) boundary condition. OpenFOAM itself is based on the Finite Volume Method, where we utilised a transient solver via the PIMPLE algorithm.

Validation

Our computation results gave insight into the airflow exiting the mouth and further downstream. The bioaerosols' trajectory appeared somewhat consistent with some speech 'clouds' captured in physical experiments, although such 'real-world' data is in very short-supply, thus a stronger dataset is required for more rigorous validation of our computational modelling (especially for longer speaking times). We are in the process of creating such a real-world dataset.

Verification

Along with comparison to 'real-world' results, we then investigated the effect of changing numerical (internal) parameters on the resultant computation. We Primarily measured the

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number of bioaerosols inhaled by the person listening (quantitative metric). We found sensitivity of this quantity upon time-step and convergence tolerance parameters.

Generally we maintained moderate precision for lower computational cost by selecting a relatively relaxed time-step value, while convergence tolerance ('residuals') were a combination of tighter (for standard solvers) & relaxed (for PIMPLE-based solver) values.

The bioaerosols' motion tended towards being bounded more within a cylinder of decreasing radius when we reduced the time-step value (see Appendix for some visualisations), which we believe is less representative of real-world flow (even though, generally, this larger time-step should decrease accuracy).

Results

Preliminary qualitative results of our computations of speech-driven airflow carrying bioaerosols follows. Also includes summary of our custom-developed modelling of speech-driven airflow and nose-based breathing.

Bioaerosols snapshot

Below is a snapshot in time after 15 [secs] of a person speaking while the other person is positioned 1 [metre] away (Figure 1). The person listening is downstream of the person speaking, and directly facing that person. The listener is breathing normally through only their nose.

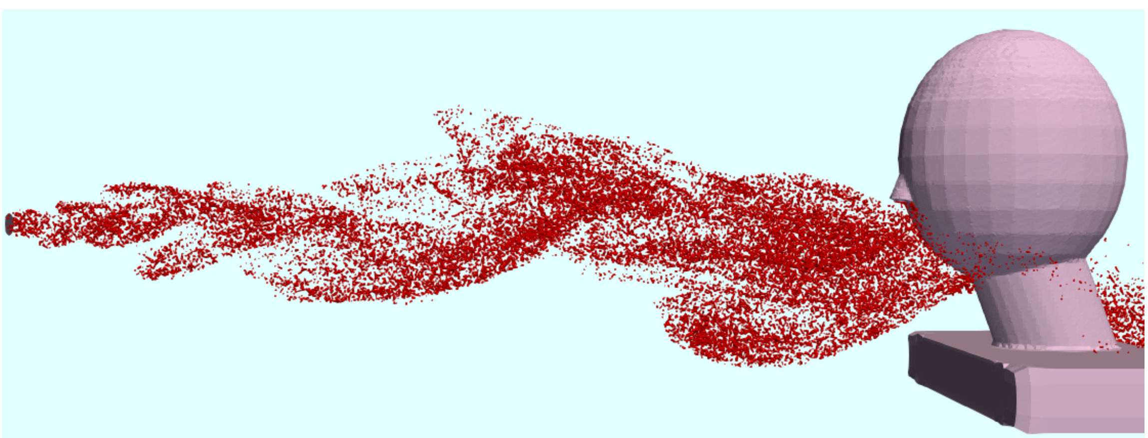

Figure 1: Snapshot of bioaerosols' positions generated by a person speaking (on left side).

Essentially, the bioaerosols travel downstream of the speaker (from the left) and towards the person listening. Some particles are inhaled by the listener, while most other either flow past the face region or stick to the person.

Discussion

Our computation involves custom-developed 'boundary conditions' that represent both airflow (generated due to speech) out of someone's mouth, and breathing through a human nose (including both nostrils). The airflow out of the mouth was assumed as qualitatively matching the resultant particle-cloud's shape with limited real-world dataset (we varied internal parameters until an acceptable visual match was found), while the breathing airflow was assigned a flow-rate & direction based on real-world measurements.

Conclusion

We have given some details of our computational virus-transmission model of a scenario of a person talking, who is emitting bio-aerosols, while another person is listening. We'll be updating our modelling & validation (and verification), with all subsequent development and information available within our research space. Again, we envision & hope our model has the potential to accelerate research & innovation of airborne-disease interventions via novel, non-pharmaceutical means.

References

[1] J. Lexchin. ”Can a pharma company change? Profit, not altruism, motivates COVID-19 vaccine development.” *The Conversation*. Accessed: February 15, 2025. [Online]. Available: https://theconversation.com/can-a-pharma-company-change-profit-not-altruism-motivates-covid-19-vaccine-development-151739

[2] ”COVID-19 Pandemic.” *Our Wold in Data*. Accessed: February 15, 2025. [Online]. Available: https://ourworldindata.org/coronavirus

[3] ”Prioritizing diseases for research and development in emergency contexts.” *World Health Organization*. Accessed: February 15, 2025. [Online]. Available: https://www.who.int/activities /prioritizing-diseases-for-research-and-development-in-emergency-contexts

[4] ”International Treaty on Pandemic Prevention, Preparedness and Response.” *Wikipedia*. Accessed: February 15, 2025. [Online]. Available: https://en.wikipedia.org/wiki/International _Treaty_on_Pandemic_Prevention,_Preparedness_and_Response

[5] H.C. Yalcin, and A. Kaushik, ”Support of intelligent emergent materials to combat COVID-19 pandemic”, *Emergent Materials*, Vol. 4, pp. 1–2, March 2021. Accessed: February, 15, 2025, DOI: 10.1007/s42247-021-00189-3. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/ PMC7944717

[6] L. Balatinec, T. Uroić, and H. Jasak, ”Open-Source CFD Analysis of Nasal Flows”, *OpenFOAM Journal*, Vol. 1, pp. 2–26, Sep. 2021. Accessed: February, 15, 2025, DOI: 10.51560/ofj.v1.38. [Online]. Available: https://journal.openfoam.com/index.php/ofj/article/view/38

[7] ”Computational prediction of bioaerosols flow around face-shields”, *GitHub*. Accessed: February 15, 2025. [Online]. Available: https://github.com/TessellateDataScience/faceShield Optimisations/blob/main/foamCases/3D_LES_particles/comms/posterA3.pdf

Appendix

Below is further visualisation of timestep-dependant bioaerosols' motion, with largest time-step shown at top (smallest time-step shown at bottom).

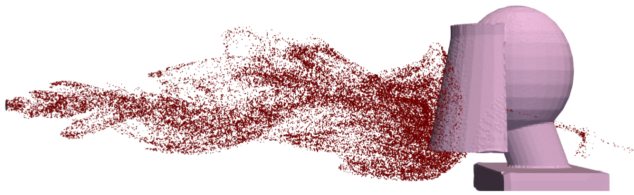

Figure 2: time-step = Largest

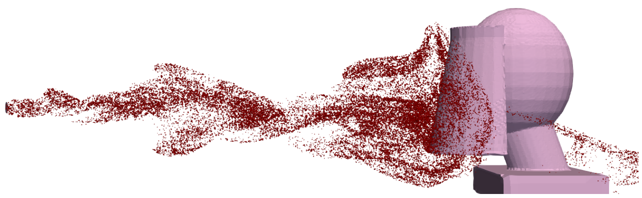

Figure 3: time-step = Larger

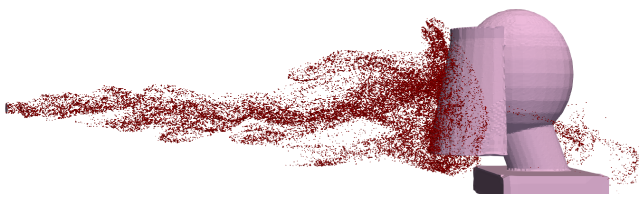

Figure 4: time-step = Smaller

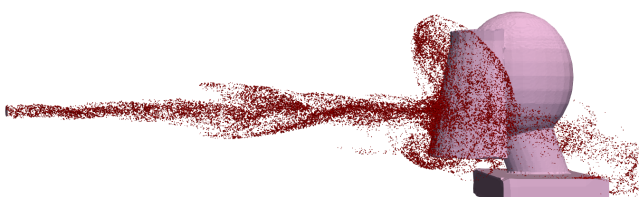

Figure 5: time-step = Smallest