Computational prediction of bioaerosols flow around face-shields

Design optimisations of a potentially innovative component of pandemic mitigation

Pandemics: prepping for the next

We're attempting to convince ourselves that at a public-health level we can have more holistic mitigation systems in-place for next time. This would reduce the over-reliance on Big Pharma [1] which has demonstrated is more interested in profit [2] than providing vaccines to those in need.

We target airborne virus transmission of COVID-19, with hopes that innovation around surface transmission concurrently occurs. We base our research on the more-appropriate technology of Personal Protective Equipment, such as face-shields, with hopes decentralised systems of manufacturing are feasible: both using more cutting-edge methods such as 3D Printing and conventional methods.

Computational science: increasing importance in the digital era?

Computational approaches have made significant effects on health & medicine research, implicit via creation of new journals specifically for this methodology (such as Nature Computational Science) and more suggestively a higher proportional of these scientists being employed by the pharmaceutical industry. We attribute this to significant cost-savings possible (exponential increases in computing power per dollar, for example).

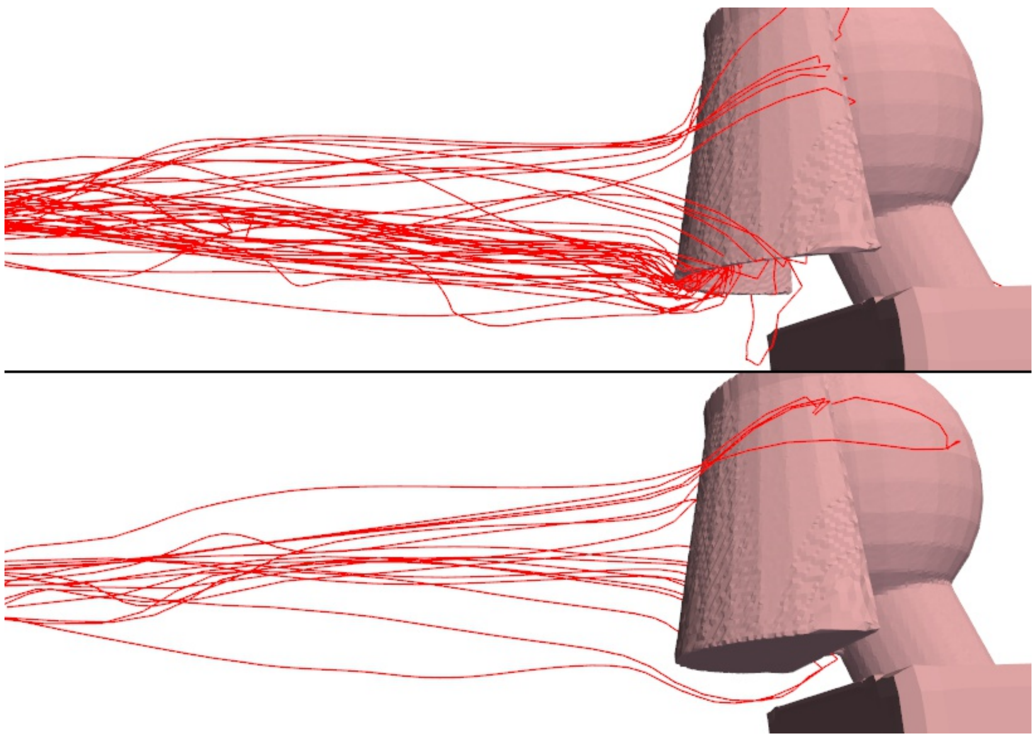
Our computational methodology

We leverage Computational Fluid Dynamics and in particular the open-source OpenFOAM software, which retains fully-inclusive licensing rights that removes the ability to 'wall-off' potential avenues to innovation in this fluid-dynamic space.

As part this we configured a low-cost mini-supercomputer (fancy name for a server) to allow parallel processing of our computations to speed them up dramatically. We bought components from data-centre & government hardware resellers, to allow easiy 'horizontal scalability' if required.

Computational findings: bioaerosols' trajctories

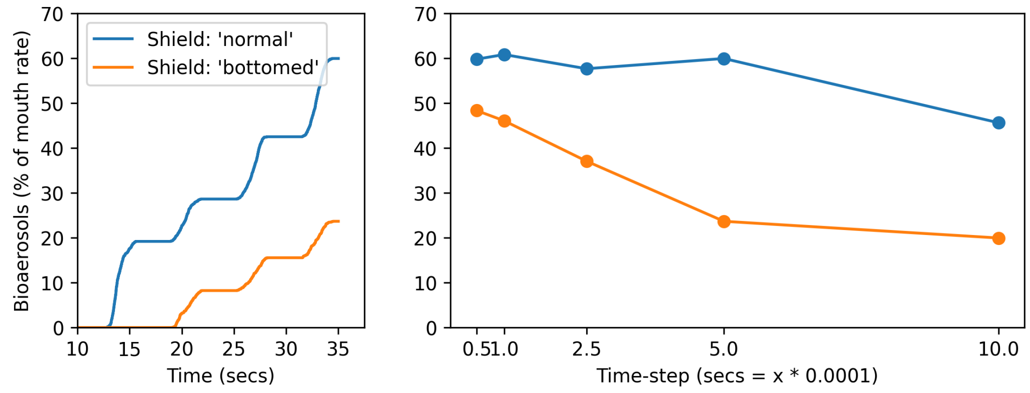
Qualitative features of bioaersols' trajectories as they flow from the emitters mouth to another person wearing a face-shield are below. Upper section of image shows the flow around a conventional shield, while lower section of image shows the identical mouth airflow (due to some computational 'magic') around the same shield but with a bottom surface added.



For the conventional shield, the concentration of bioaerosols appears greater towards the centre of the shield (in a horizontal plane) resulting in less inhaled at larger distances away (nearer the shield's sides in other words), with almost all bioaerosols inhaled passing the shield's bottom edge within half the width. For the 'bottomed' shield, less spatial concentration tendencies are present. Also, significantly less bioaerosols are inhaled (and hence less travel under the shield).

Computational findings: verification

Quantification of the bioaersols' inhaled by the shield-wearing person is below. Specifically the graph shows the total number of these particles inhaled after 35 [secs] of continuous speech (left), for both the conventional and novel face-shields. Also shown is the effect of varying the 'time-step' (numerical) parameter on this dependent variable (right).



The number of bioaerosols inhaled increases in a linear trend when someone is speaking constantly without pausing between sentences and when thinking, for example, with variation away from the trend due to the other person's inhalation rate thru their nostrils. Across differing shield designs a significantly reduced number of bioaerosols are inhaled by the person wearing a shield with a bottom (horizontal) surface added.

For an arbitrary time-step of 0.0005 secs, this reduction ratio is ~ 35 %. Yet changing the time-step has a significant effect on this ratio, cutting it to less than half when a smaller time-step is used.

Verification: remarks

The quantification above demonstrates the sensitivity of our computational results on the time-step value selected. This is perhaps expected, as although our modelling of the speech-driven airflow out of the mouth is based on randomisation, it is dependent upon time (used as it's input value to generate it's random output).

As our research objective is increasing effectiveness, high accuracy is perhaps not strictly required. In other words, we deem conventional accuracy assessment (validation) as less important as robust comparison of predictions across our face-shield 'designs'. Thus we ensure predictions have consistent trending of continuous-type numerical parameters even if we haven't validated our predictions' accuracy against real-world experiments.

Further development

We now proposed further design optimisations are undertaken. Briefly, this couples the computational-based method we've used with human-based 'ideation' techniques. This starts we qualitatively divergent design parameters being selected as an initial guess. Then computational predictions are captured for each parameter, with the most promising selected for further computational analysis. We envision this approach allows greater probability of achieving breakthrough innovations (attempting to ensure the parameter space is more adequately searched).

'Fine print'

1. How much power do drug companies have? | DW Documentary: https://www.youtube.com/watch?v=-z_W3yRA9I8

2. Profitability of Large Pharmaceutical Companies Compared With Other Large Public Companies | PubMed: https://pmc.ncbi.nlm.nih.gov/articles/PMC7054843/

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