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HVAC System Sizing Based on Computational Fluid Dynamics

5 October 2023 | Technical Topic Webinar

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EIT Lecturer and Course Coordinator in Mechanical Engineering

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Introduction - Presenter

Vijay Kumar Veera

- Qualified Aerospace Engineer with over 12 years of experience in using CFD methodologies to simulate industrial and academic problems.
- Obtained an M.Phil degree in Engineering from Cambridge University in UK and has M.Tech and B.Tech degrees from Indian Institute of Technology in Bombay and Madras respectively. His expertise is in capturing Fluid flow phenomena using computational methods. He has worked with major organizations in Australia and UK with Red Bull F1, Mercedes F1, Boeing, Airbus, Thales, DSTO, Fisher & Paykel some of the notable clients.
- In his current role as a Unit lecturer and Course Coordinator at EIT, he has been instrumental in developing lecture materials for teaching Advanced fluid dynamics and Aerodynamics units for students pursuing Master of Mechanical Engineering. His passion is in teaching computational fluid dynamic techniques for solving real world problems, which are becoming highly popular with professional engineers wanting to advance their careers to the next level. He is a passionate educator and an advocate for using real world examples in the classroom.

HVAC SYSTEM SIZING THROUGH CFD

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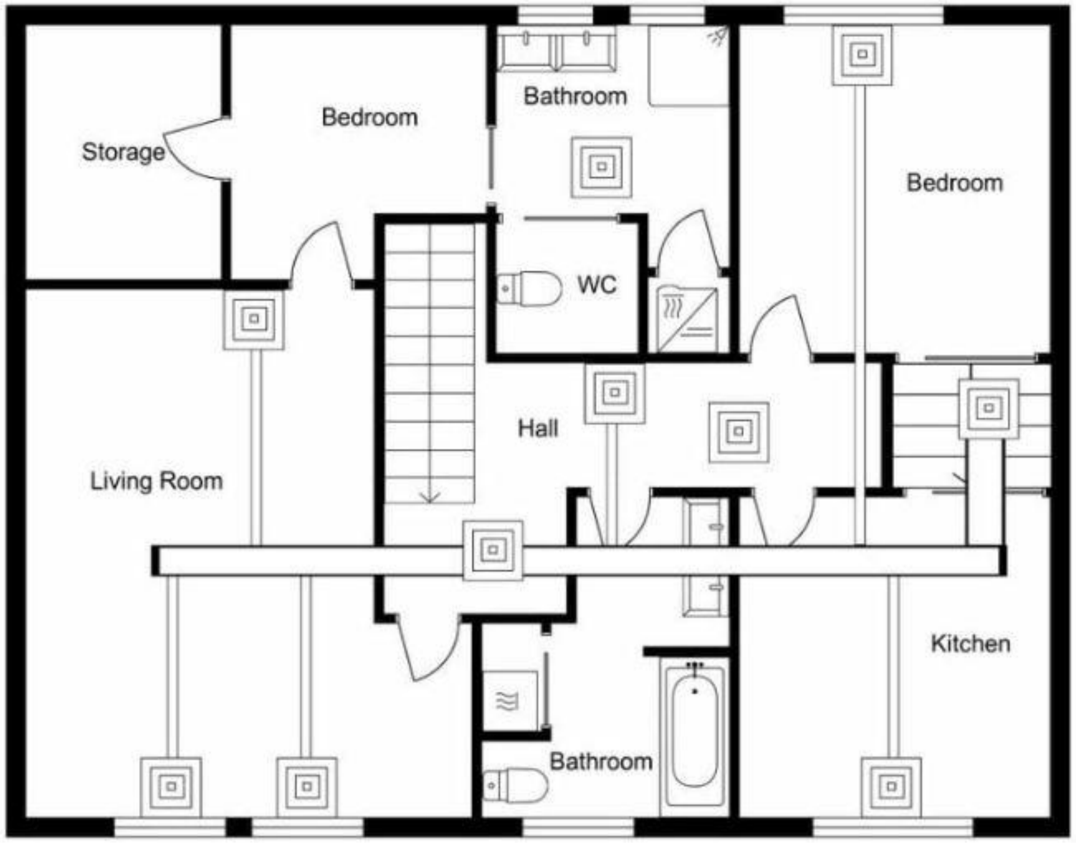
PROBLEM STATEMENT

- Conduct a CFD analysis of a typical apartment.
- Include typical sources of heat such as electronic appliances, desktop computers etc.
- Identify regions of high velocity.
- Identify thermal hot spots.
- Evaluate HVAC system efficacy and suggest improvements.



GEOMETRY CREATION

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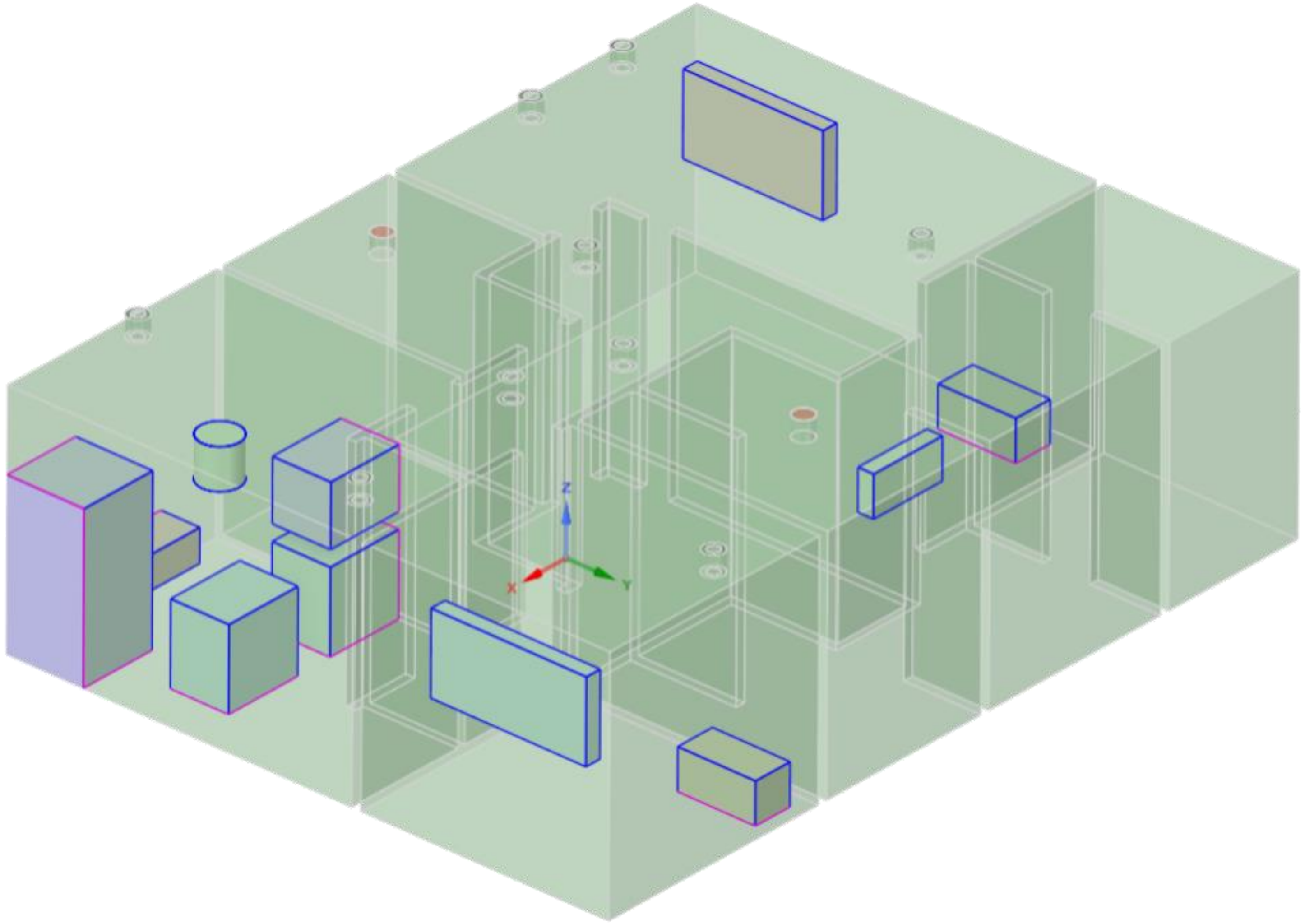
ANSYS SPACECLAIM WORKFLOW

- Create 3D geometry from plan.
- Identify major heat sources. Eg. TV, Fridge, Washing Machine, Desktop etc.
- Create appropriate geometry to model inlets and exhausts.
- Ensure heat sources either coincident with fluid surface or have sufficient distance.



CFD SIMULATION METHODOLOGY

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Repeat the process if necessary

GEOMETRY CREATION
- Identify the fluid domain to capture necessary physics

MESH GENERATION
- Generate a mesh that captures regions of high gradients with sufficient resolution

CASE SETUP
- Choose the appropriate models to represent flow physics
- Specify the correct boundary conditions
- Choose the solver settings necessary to run the solver.

RUN SOLVER
- Solve the governing equations iteratively until the residuals drop to low values.

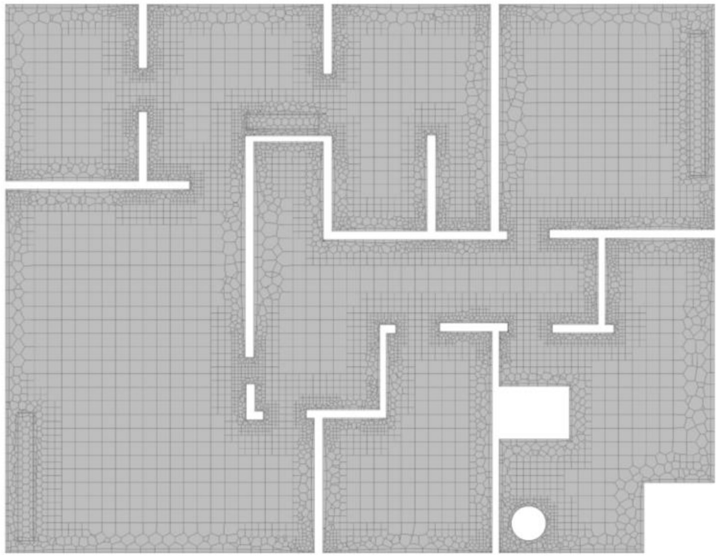
POST PROCESS
- Visualise the flow field by plotting contours, vectors, streamlines and animations.

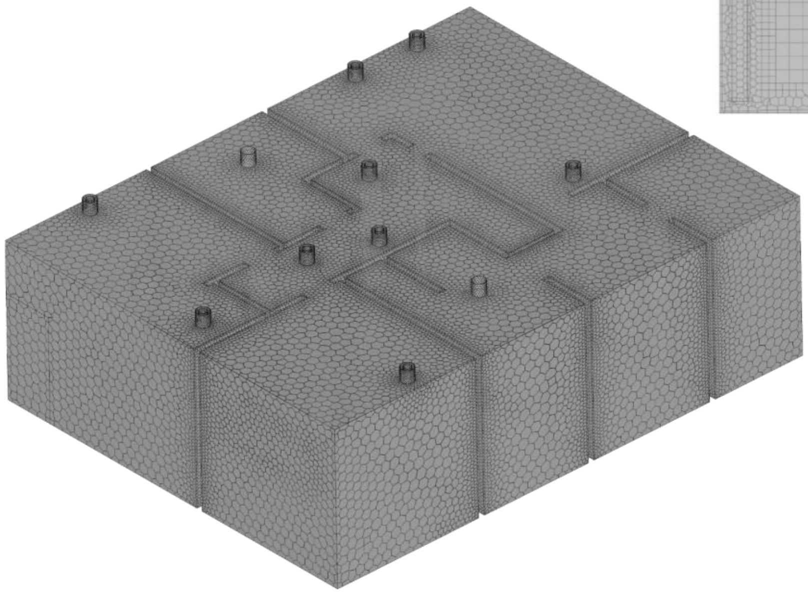
VALIDATE RESULTS
- Compare with available experimental data to evaluate the efficacy of the CFD model.

MESH GENERATION

FLUENT WATERTIGHT MESHING WORKFLOW

- Choose appropriate cell sizing to adequately resolve features in the domain.
- Ensure cell sizes resolve any gaps between the apartment walls and the heat sources.
- Assign appropriate cell zone and boundary conditions for easy case setup.
- Use Poly-hexcore methodology for mesh generation.
- Limit cell count to 512000 due to Ansys student constraint.





NUMERICAL MODEL

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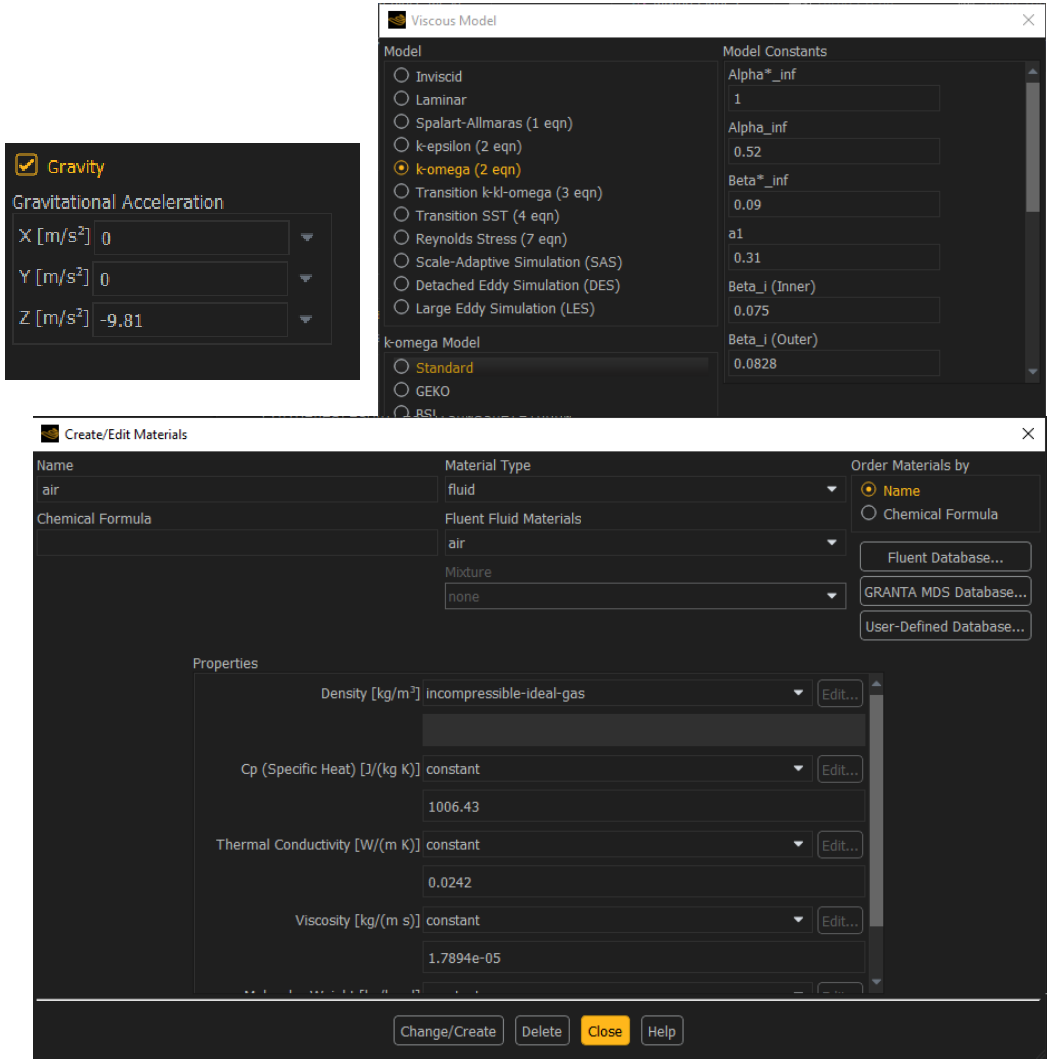
FLUENT SOLVER SETUP

- K-W SST for turbulence closure.
- Gravity vector to capture buoyancy driven flows.
- Energy equation and incompressible ideal gas for density.



BOUNDARY CONDITIONS

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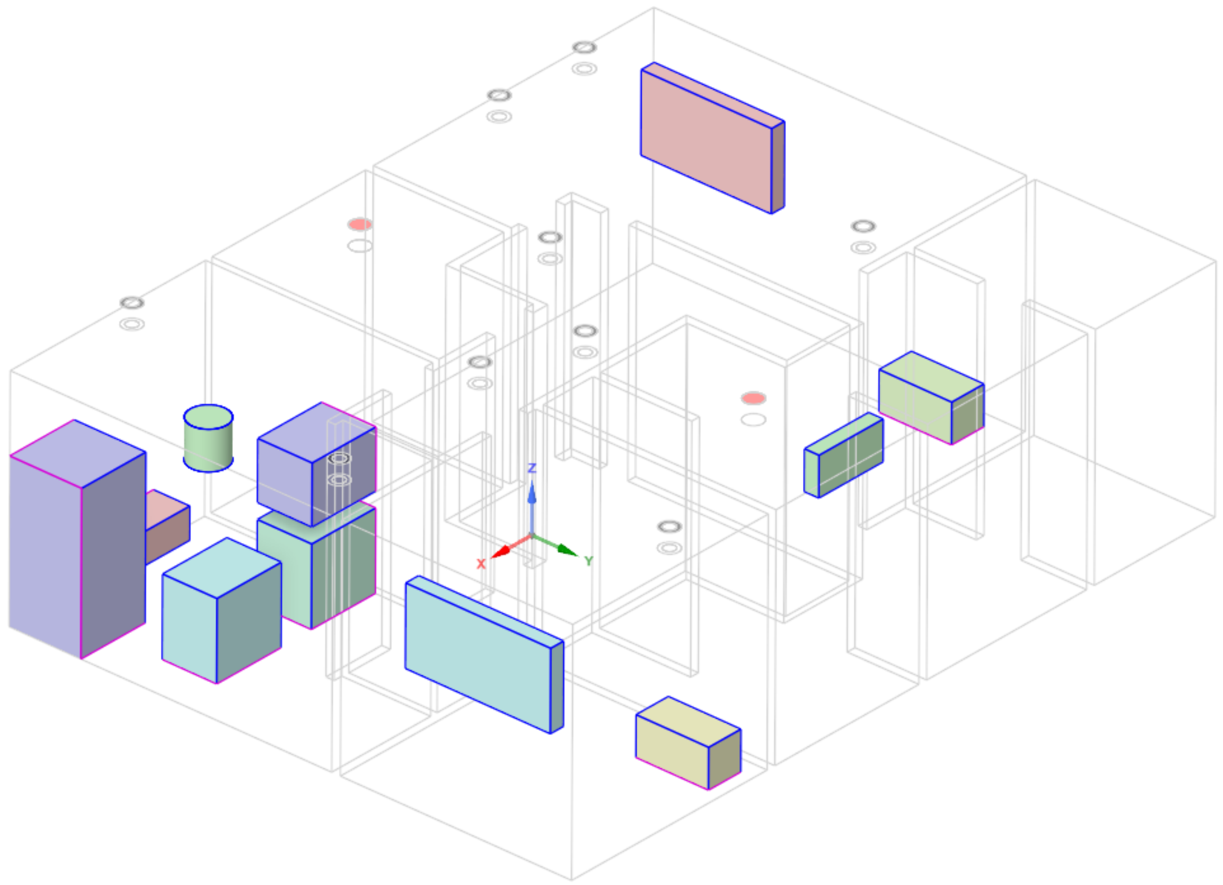
FLUENT SOLVER SETUP

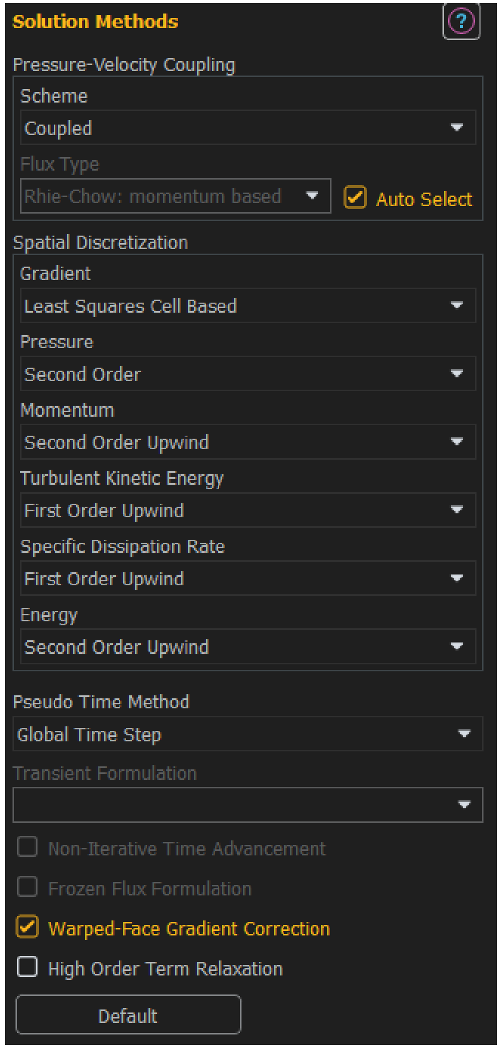
- Volumetric sources responsible for heat generation. Create heat in the apartment.
- Inlets – provide cold air to room to absorb heat generated.
- Outlets - means for used air to exit the apartment.

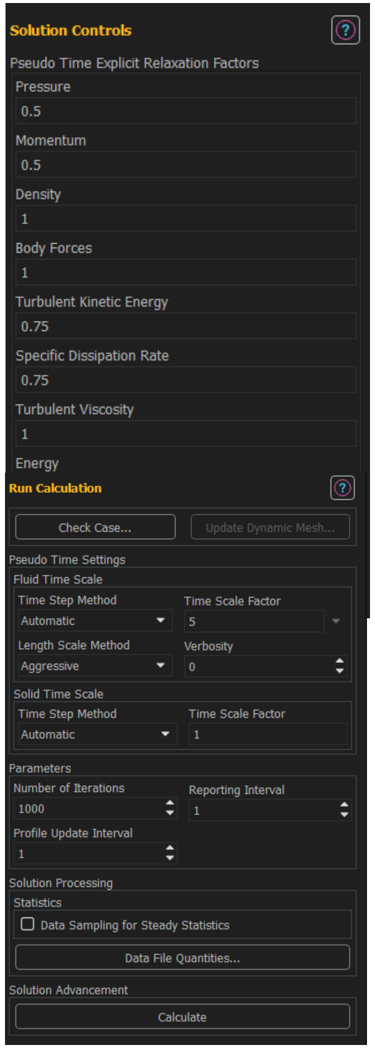


SOLUTION METHODS

FLUENT SOLVER SETUP

- Second order discretisation for transport variables.
- Coupled scheme for pressure-velocity equations.
- Pseudo-transient time step.

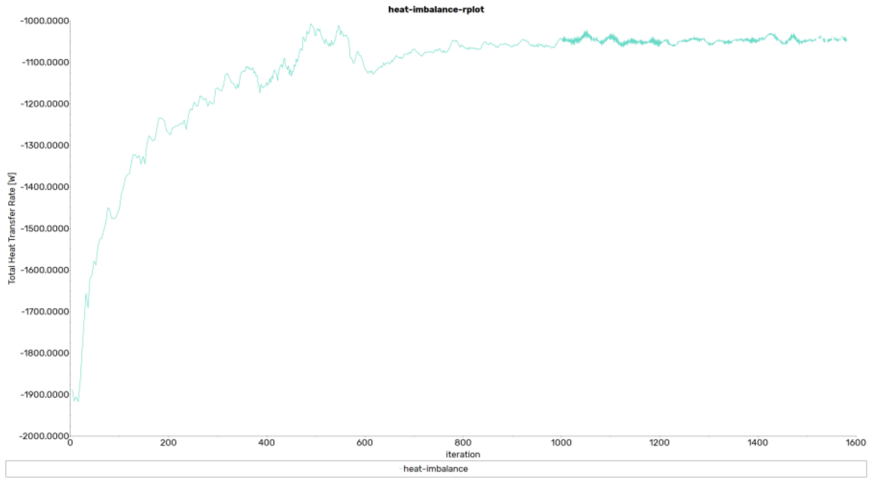


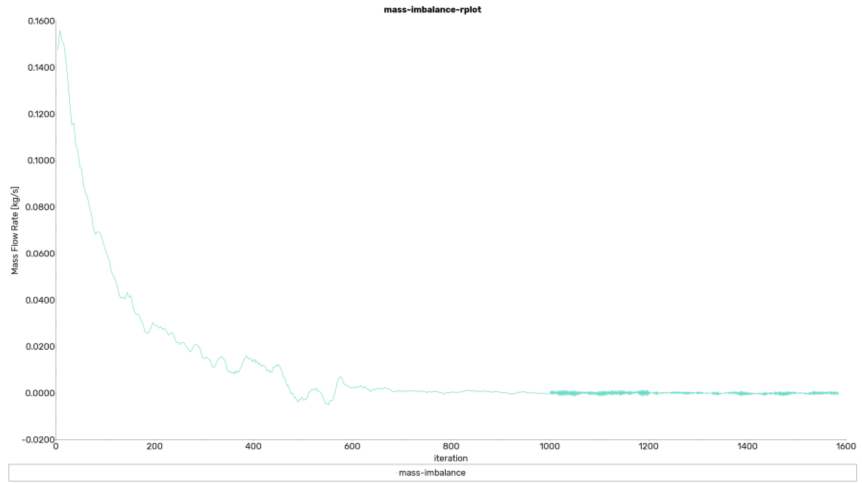


SOLUTION MONITORING

FLUENT SOLVER SETUP

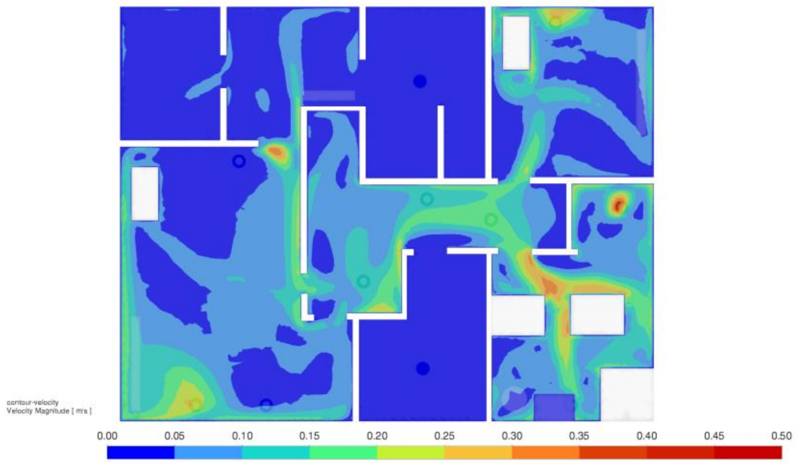
- Create "Solution monitors" to track quantities of interest in the simulation. Eg. Average exit temperature, Average velocity at areas of interest.
- Track residuals to ensure they drop by atleast 3 orders of magnitude.

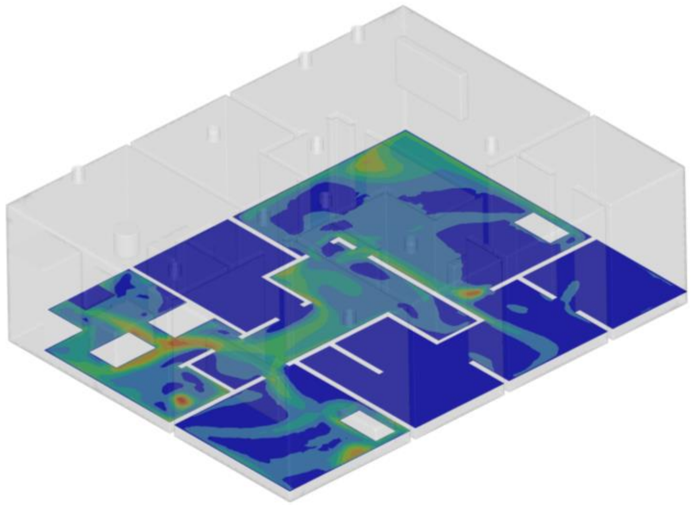




VELOCITY CONTOURS

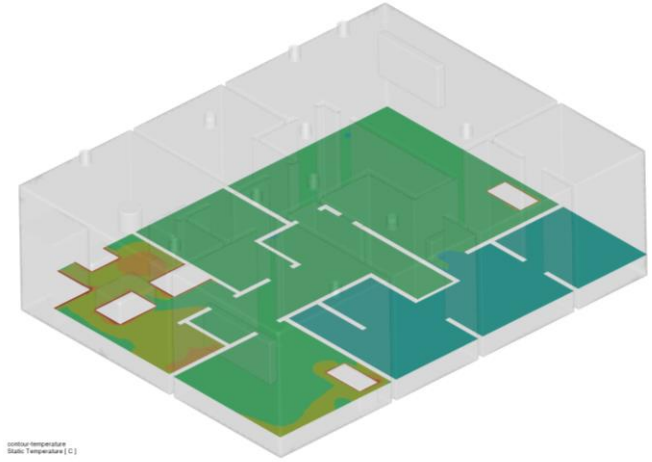
- Velocity contours useful to identify areas of faster airflow.
- Regions with lower airflow expected to be poorly ventilated.





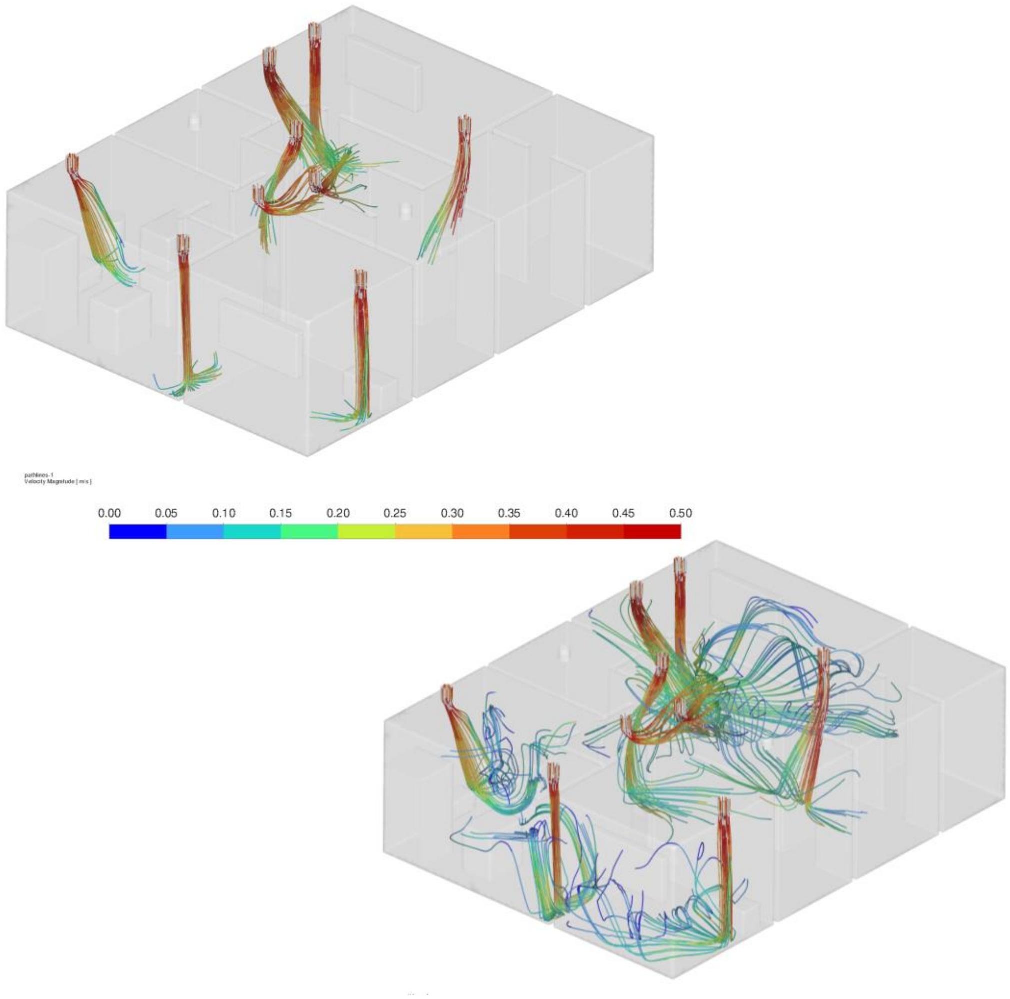
TEMPERATURE CONTOURS

- Identify warmer regions and potential hotspots.
- Provide advice to adjust supply and return locations to improve temperature uniformity.



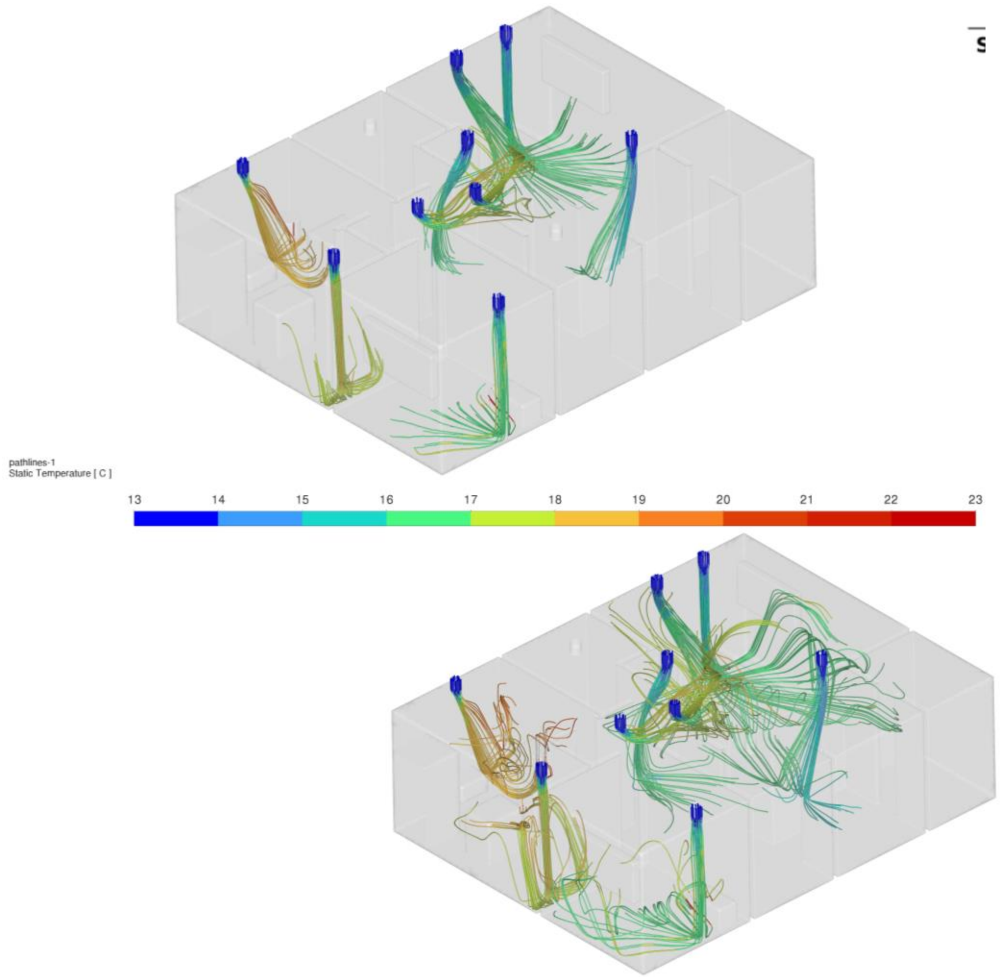
VELOCITY STREAMLINES

- Velocity streamlines indicate regions where jet penetration is sub-optimal.



TEMPERATURE STREAMLINES

- Temperature streamlines help differentiate warmer regions from the cooler ones.



SUMMARY AND CONCLUSIONS

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- Brief introduction to analysis of apartment HVAC systems through CFD.
- Visualised flow patterns to identify areas with higher velocities and thermal hotspots through CFD.
- Evaluate efficacy of the HVAC system in ventilating the space.
- Setting an exhaust in the kitchen a possible solution to reduce temperatures in the kitchen.
- More cost-effective than conducting experimental analysis.

Hongjun, R. and Dimitri, M., 2005. Preliminary Design of a 2D Supersonic Inlet to Maximize Total Pressure Recovery; In AIAA 5th ATIO and16th Lighter-Than-Air Sys Tech. and Balloon Systems Conferences pp. 3-5.

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Undergraduate Certificate in Mechanical Engineering	12 February 2024
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