

Development of Customized Indoor Air Simulator using OpenSource Libraries

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June 29th 2016

presented by ILYOUP SOHN Ph.D

Outline

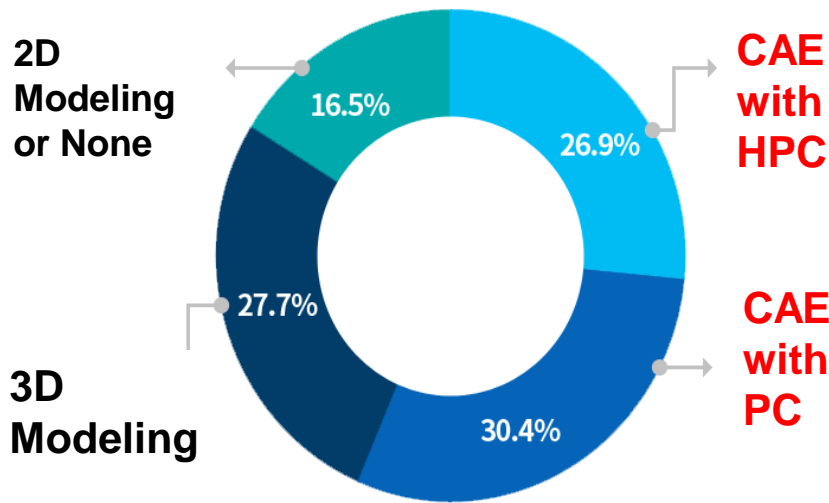
- ▶ **Background & Introduction**
- ▶ **Development Process**
 - Pre-Processing
 - Solving
- ▶ **Validation for Simple Air Indoor Flow Case**
- ▶ **Results and Discussion**
- ▶ **Summary**
- ▶ **Future Work**

Background – Motivation

United States



- Utilizing CAE (Modeling & Simulation, M&S) for **55.8%** of the manufacturing industry (over 90 % when 2D-CAD included)

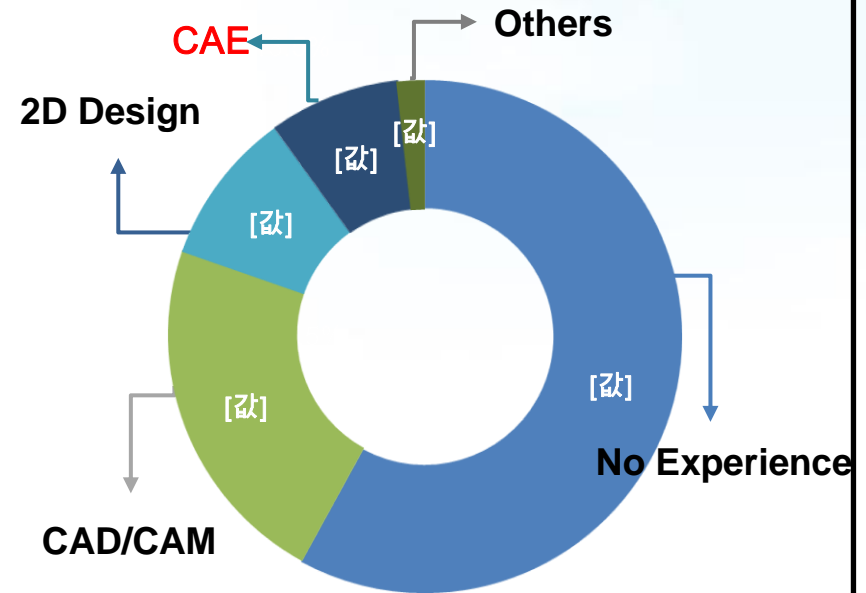


<Ref : Intersect360, "HPC Trends and Market Update for 2012">



Korea

- Utilizing CAE (Modeling & Simulation, M&S) for **8.2%** of the manufacturing industry



<Ref: KISTI, "Investigation of M&S Needs for SME"(2014.7)>

Conglomerates of S. Korea use CAE techniques to develop new products, but small and medium manufacturers ?

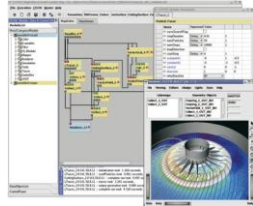


HPC Modeling and Simulation (M&S) Center

1 Development of M&S SW

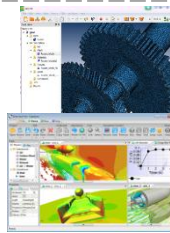
HEMOS : Workflow

- Step-by-Step Process
- Simple Interface
- Easy M&S procedure



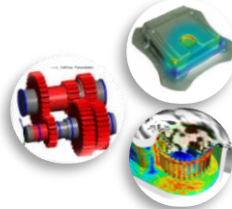
HEMOS : Structure & Fluid

- Structure : Calculix, Code-Aster based FE solution
- Fluid : OpenFOAM based



HEMOS+

- Customized Simulation platform
- Customized simulation tools suitable for product designer and CAE beginners



2 Supercomputing M&S Platform (Easy supercomputing)

HEMOS : Cloud

- Running M&S SW on Cloud
- Interactive Pre/Post processing
- Connecting to Supercomputer for large scale simulations



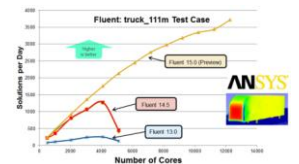
HEMOS : HPC+

- Development and Distribution of libraries for HPC
- API & DLL(Plug-in)



Support to Domestic SW

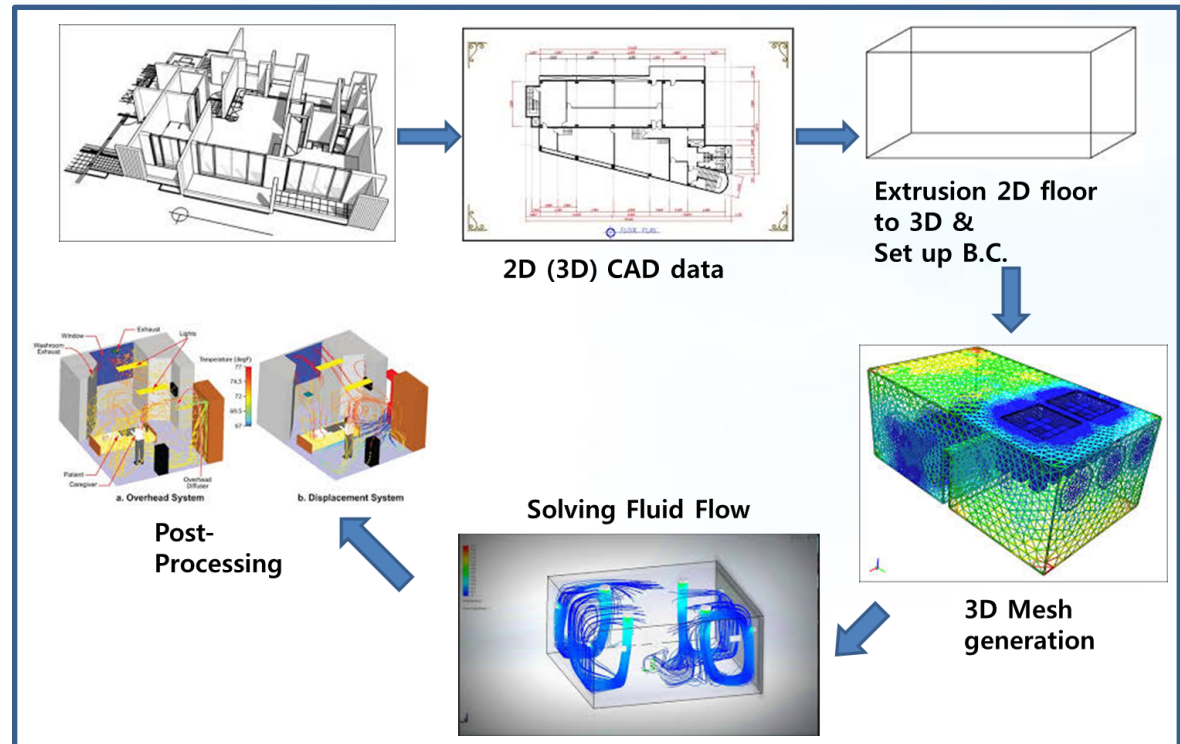
- Domestic M&S SW Parallel Performance test
- Scalability Test and performance comparison to Foreign SW



Introduction – Overview

(1) Architectural or HVAC engineers and designers need simply prediction of air flows inside open or closed spaces in houses, buildings and industrial plants.

(2) Real performance as well as positions of HVAC system inside indoor space can be analyzed through flow simulations before it is equipped.



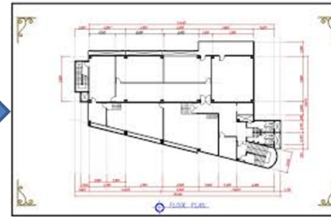
(3) Recently, energy saving becomes important issue in architectural engineering, therefore optimal positions of HVAC facilities in the unit space are significant. CFD techniques are useful to determine proper positions and specifications of them.

(4) Simple approach of CFD to HVAC area at the indoor space is needed.

(5) The real purpose of this work is understanding potentials of Open Source SW such as OpenFOAM. (Short term project due to lack of funding)

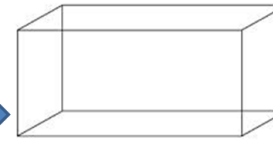
Introduction – Key issues of indoor air simulator development

1) How to import 2-D floor CAD data ?

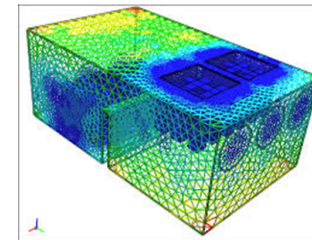


2D (3D) CAD data

2) How to generate mesh and specify boundary conditions ?



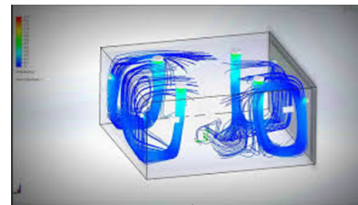
Extrusion 2D floor to 3D & Set up B.C.



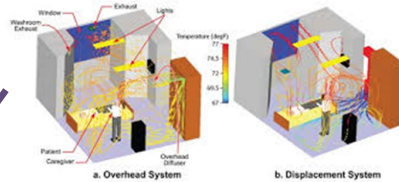
3D Mesh generation



Solving Fluid Flow



Post-Processing



5) How to show simulation results ?

3) How to solve N-S equation and with what ?
4) Which solver of OpenFOAM is proper ?

3) How to create full 3-D mesh and to control meshes ?

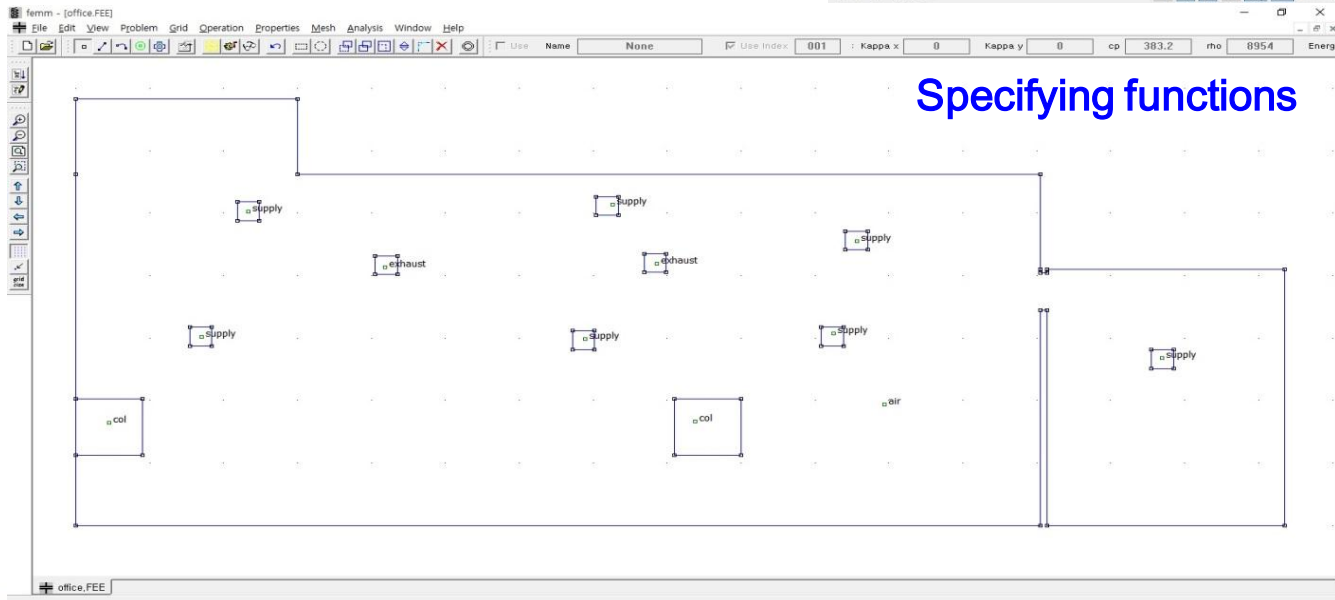
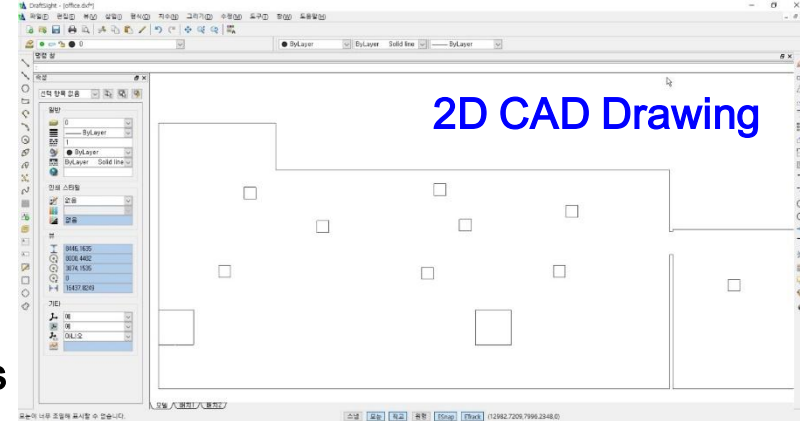
*KISTI Automated Simulator of HVAC

Development Process – Pre-Processing

■ Interface for beginners

Pre-processing using open source for electro-magnetics called FEMM (Finite Element Magnetic Method)

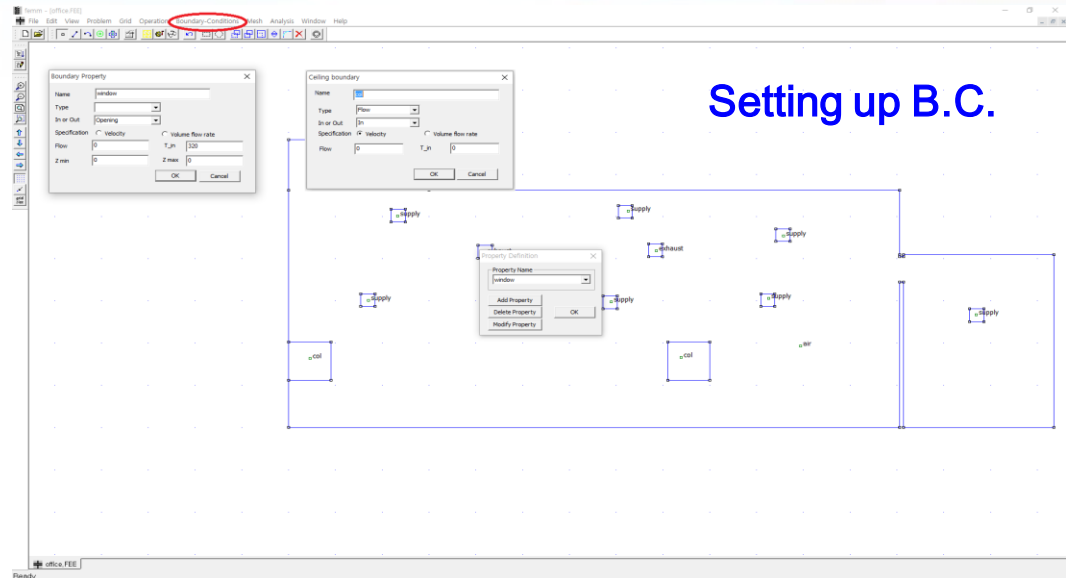
- Importing 2-D floor plan data as a DXF format
- Modifying 2-D floor data
- Auto Triangular mesh generation
- Setting up size and number of cells
- Setting up B.C appropriate for fluid flow simulations



Development Process – Pre-Processing

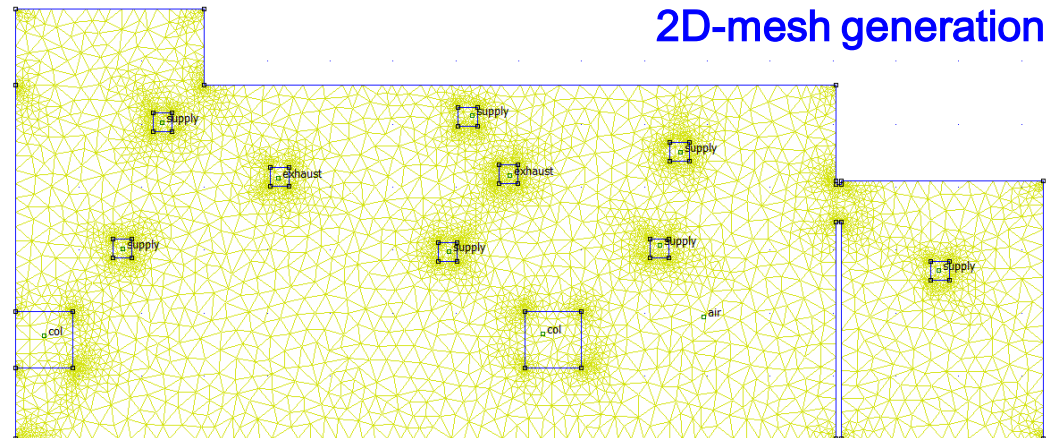
■ Setting up Boundary conditions

- Air supplier, exhaust positions, flow rate
- Windows
- Wall conditions

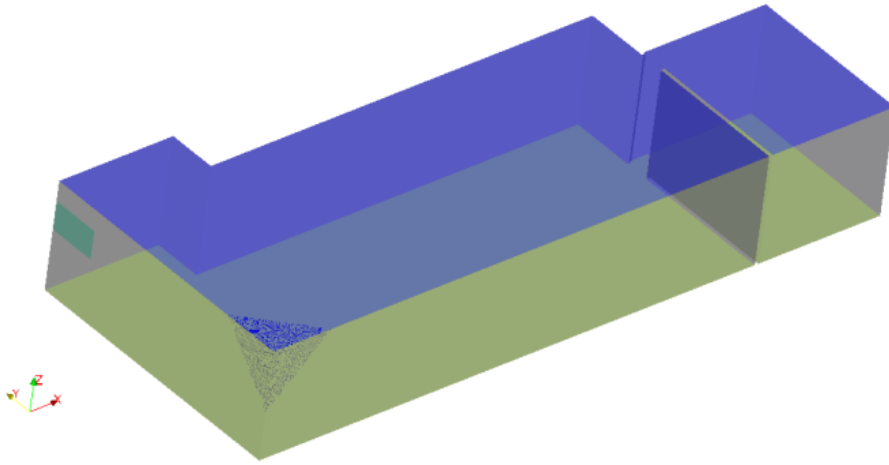


■ 2D mesh generation

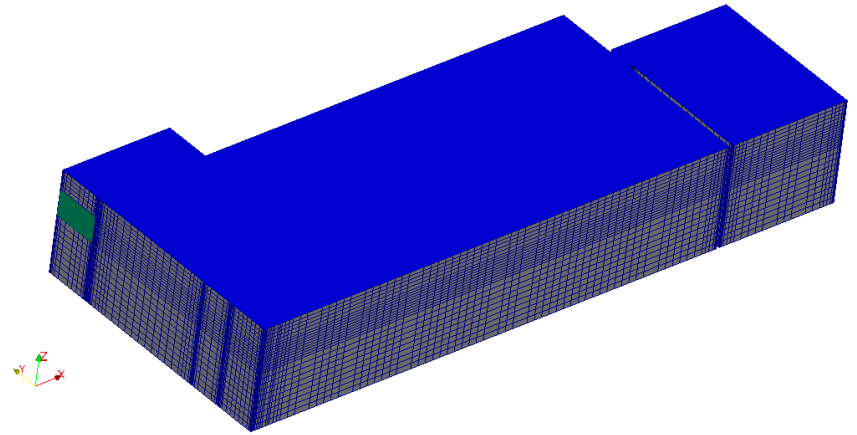
- Triangular mesh generated
- Input height and number of divisions



Development Process – Pre-Processing



2D → 3D geometry extension



2D → 3D mesh generation

STL file (2D mesh) → Converting obj (surfaceConvert) → extrude2DMesh

- Able to control cell size and number of cells accordingly
- Implementation of boundary layer at the wall has not done yet. (near future work)
 - In general, the flow speed is comparatively low so the effect of boundary layer on the entire fluid pattern is expected to be weak.
 - Still need to develop a mesh generation module enough to be stable and robust numerical simulation
 - Consider other mesh generation modules to be applied to this framework (near future work)

Development Process – Solving

○ **buoyantSimpleFOAM** : Steady-State solver for buoyant, turbulent flows of compressible fluids

- Turbulence model : Standard k-ε model

○ **Air-age FOAM** : Air age calculation based on scalarTransportFOAM

$$\frac{\partial(\rho\Phi)}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i \Phi) = \frac{\partial}{\partial x_i} \left\{ \left(\frac{\mu}{\sigma_l} + \frac{\mu_t}{\sigma_t} \right) \frac{\partial \Phi}{\partial x_i} \right\} + S_c \longrightarrow \frac{\partial}{\partial x_i}(\rho u_i \Phi) = \rho$$

- Simple prediction of air age
- Important aspect for Indoor space ventilation

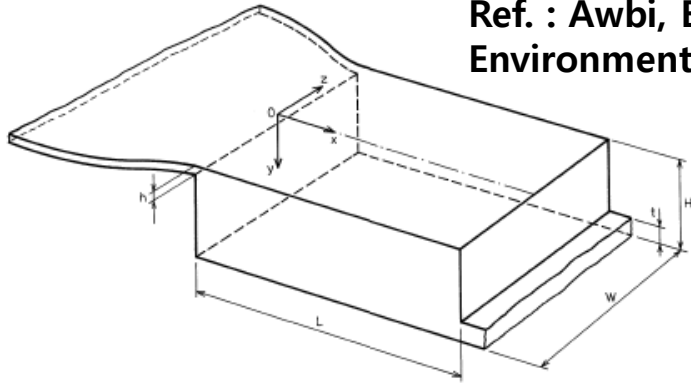
- Steady
- Incompressible
- Diffusivity neglected
- Source term → density

t : Time

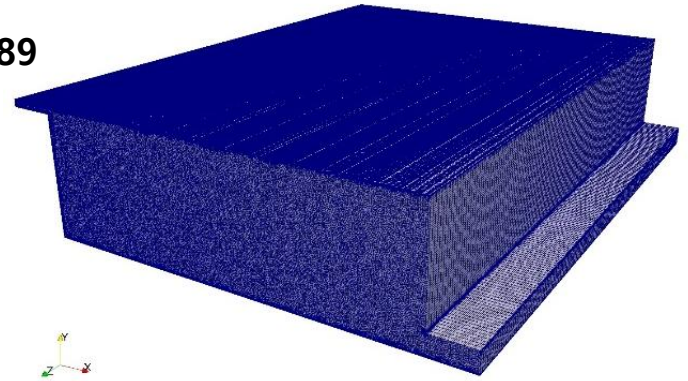
Ref. : OpenFOAM Programmers Guide

Validation – Air flows for Simple Indoor Space

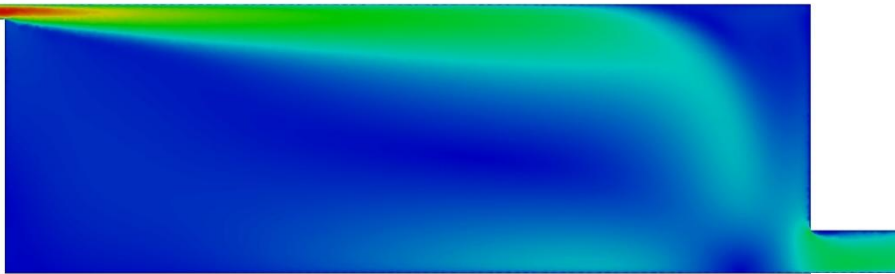
Ref. : Awbi, Building & Environment, Vol.24 No.1 1989



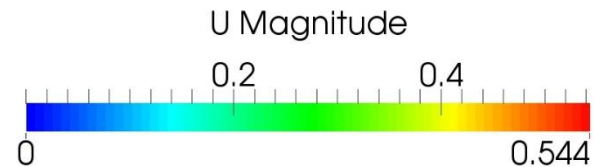
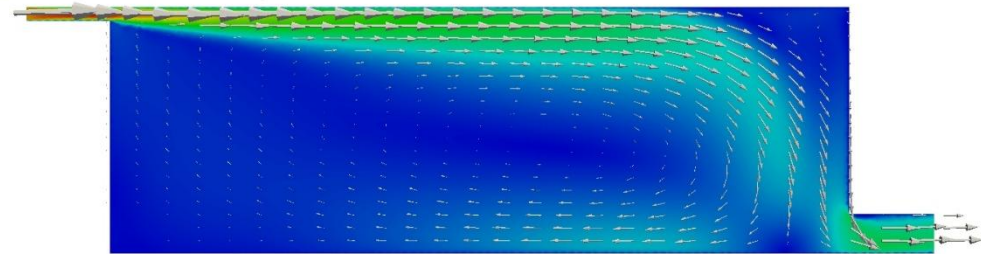
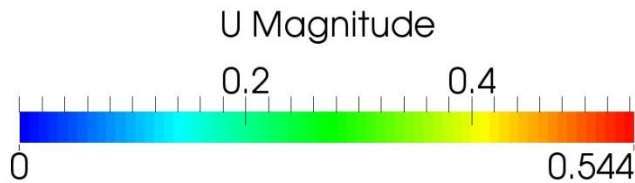
< Geometry >



< Mesh generation >

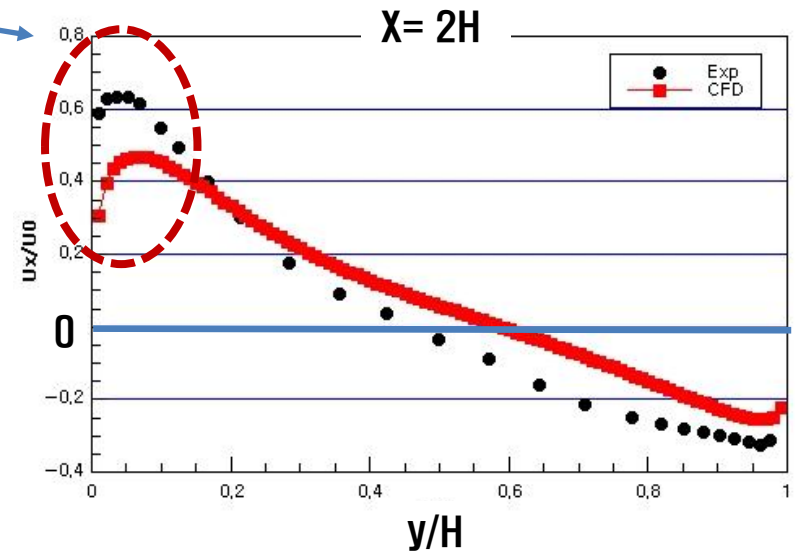
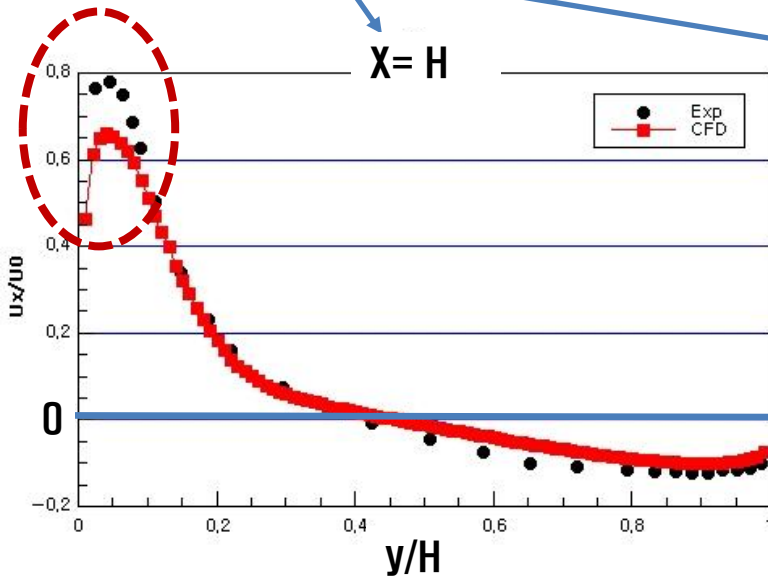
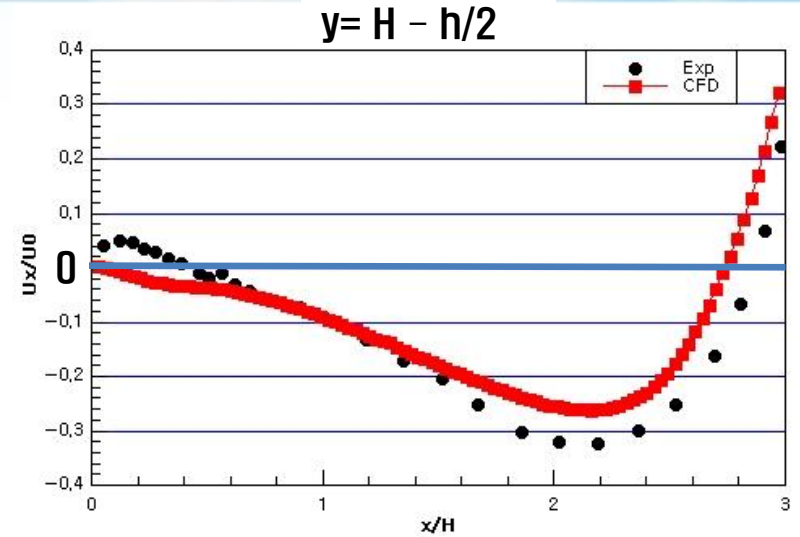
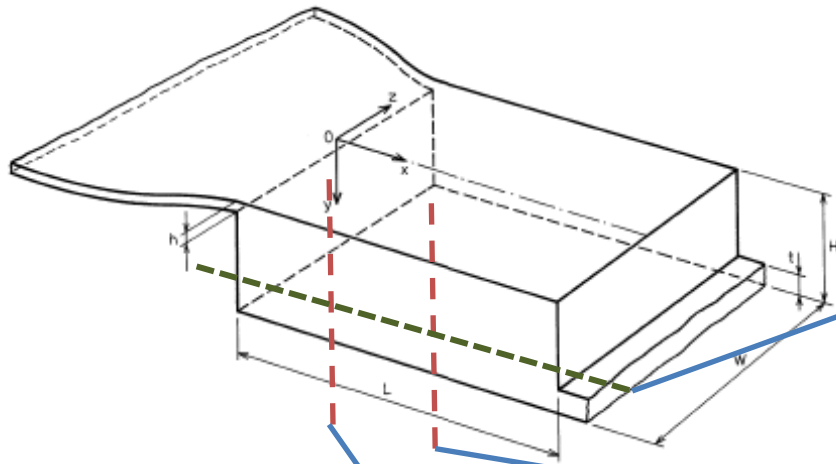


< Velocity Magnitude contours and vector >



- Near outlet exit, air flow is separated.
- Compare normalized velocity with experimental measurements

Validation – Air flows for Simple Indoor Space



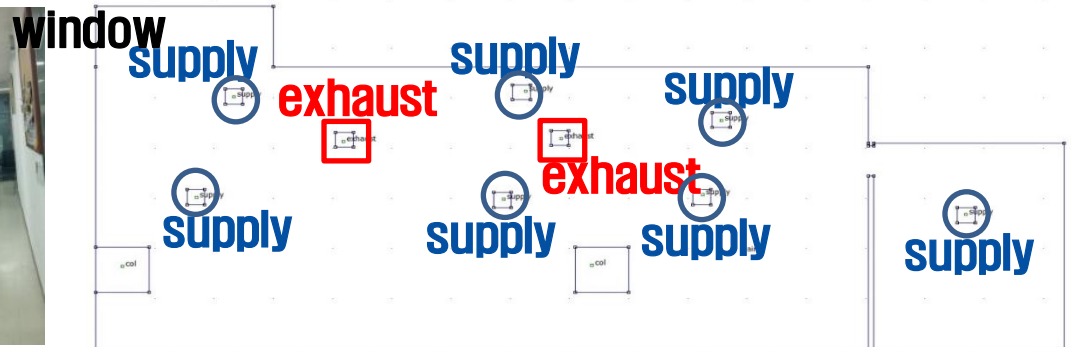
- CFD results (Red) are roughly similar to those of experiments (Black).
- Mesh generation near the wall is not sufficient to capture the characteristics of air flows near wall, which seems to cause some difference between numerical and experiment results.

Results and Discussions – Boundary conditions

◆ Overview of Air Simulation for a general type office



< Real view of Office >



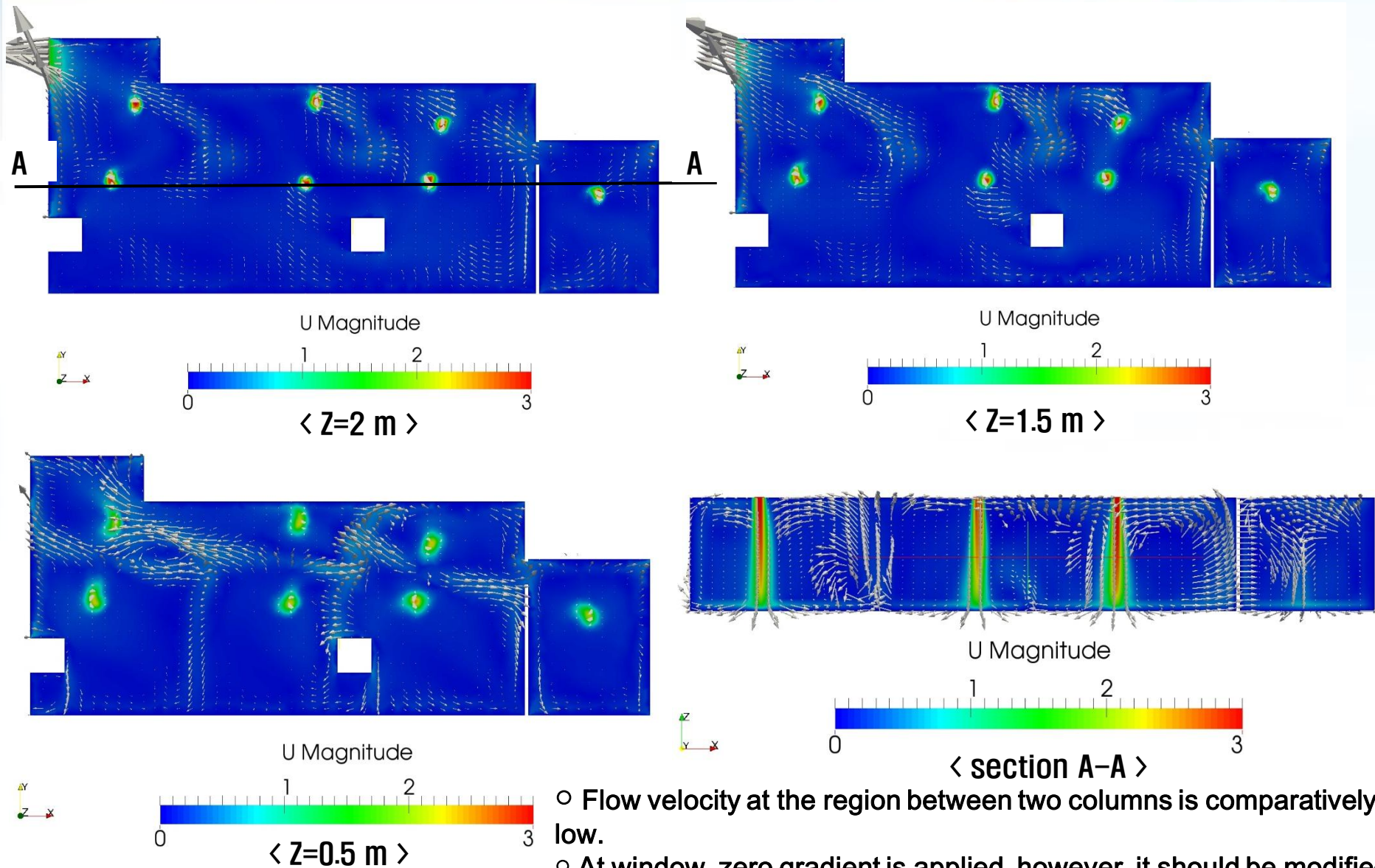
< Floor plan and Boundary conditions for CFD >

- Solve indoor air flow using KASHVAC and investigate flow pattern
- Examine the velocity magnitude and vectors for the entire space inside the office
- The ventilation performance is predicted through air age parameter

◆ Set-up boundary conditions

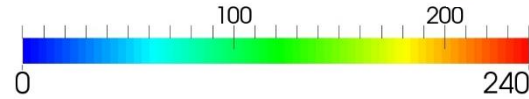
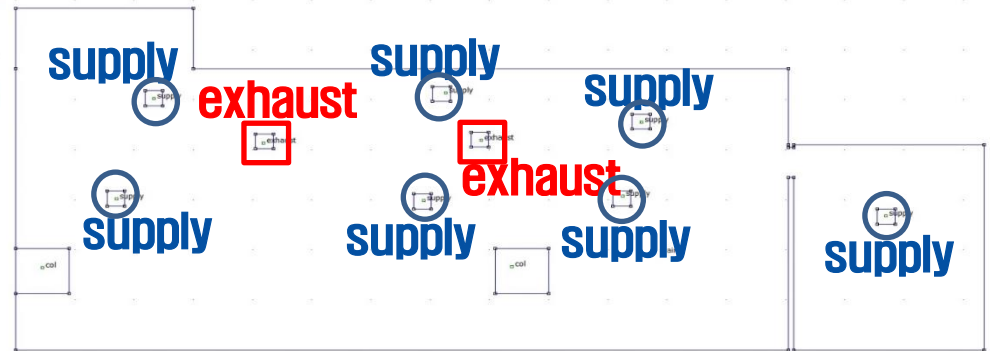
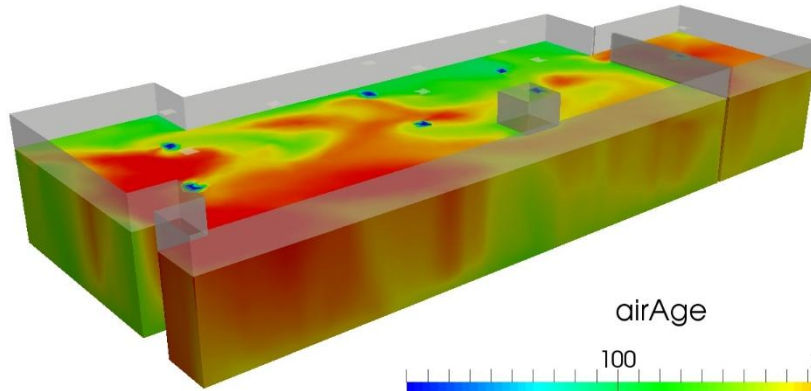
- At Supply : FixedValue U (3 m/s)
- At Exhaust : FixedValue U (3 m/s)
- At Window : Zero Gradient
- Cell conditions : Air filled

Results and Discussions – Velocity magnitude & vector

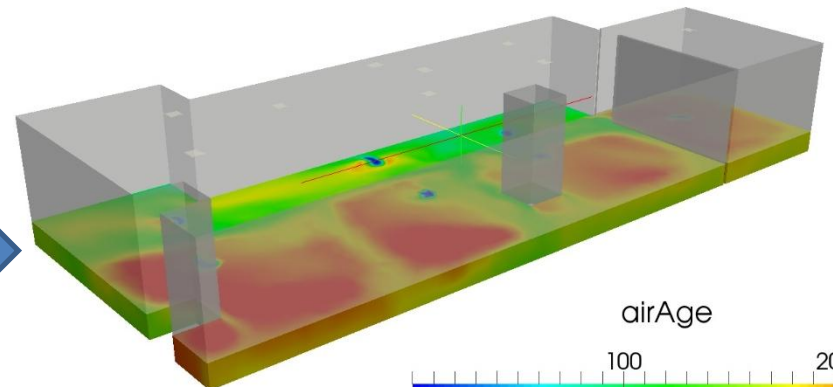
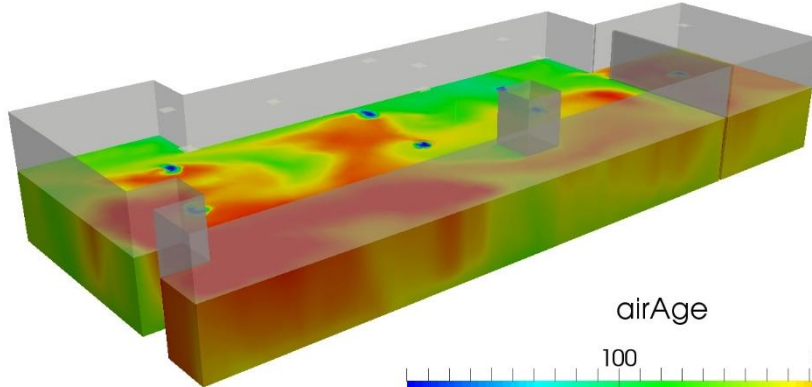


- Flow velocity at the region between two columns is comparatively low.
- At window, zero gradient is applied, however, it should be modified to define various air conditions.

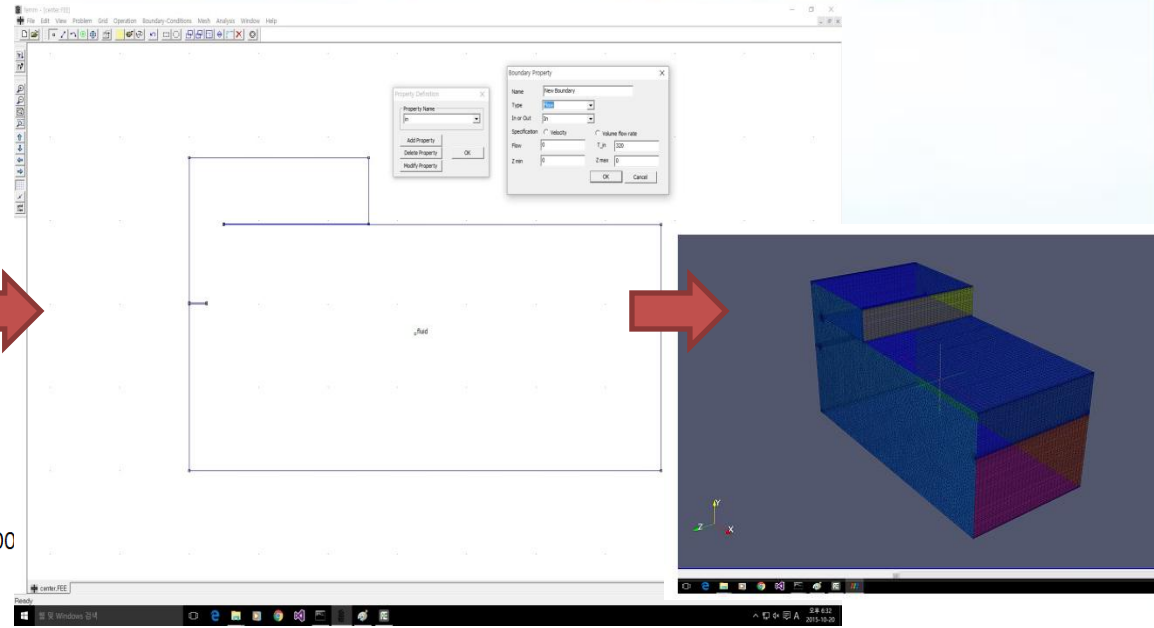
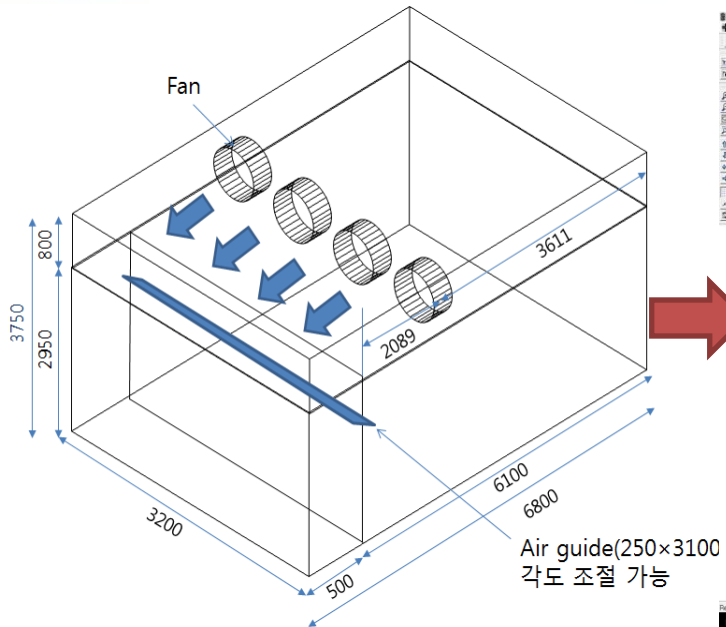
Results and Discussions – Air Age Simulation



- Air age is also an important feature in indoor air simulations.
- Air age is always found to be low at the air suppliers which are blowing new air.
- In the regions where air is circulating, air age is usually observed to be high.

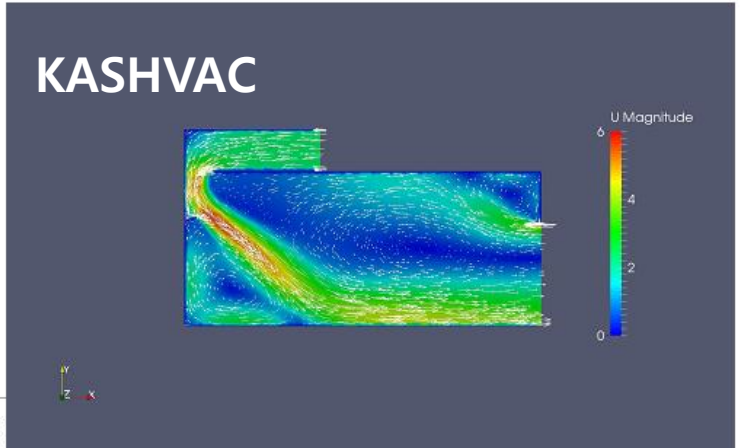
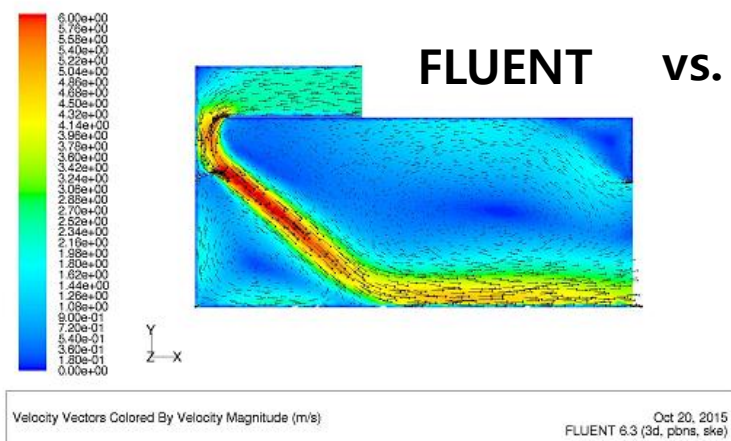


Results - Other Applications



< Drying Container / Storage >

○ KASHVAC gives flow solutions similar to those calculated from FLUENT.



Summary

- Customized indoor HVAC simulator using open source libraries has been developed (to examine applicability of open source to practical applications).
- The magnetic field simulation tool, FEMM, was chosen to use functions of CAD import and 2-D triangular mesh generation. (Do not use FEMM !!)
- Supply and exhaust boundary conditions were added and the effect of window was implemented through zero-gradient.
- buoyantSimpleFoam solver was selected to solve air flows.
- We tested flow simulation for simple indoor air benchmarking test and got simulated flow pattern roughly similar to experimental measurements.
- Cells for boundary layer is not quite good, which makes some difference of flow results between numerical and experimental data.
- Air-age was simply implemented using OpenFOAM solver and predicted for a sample office indoor space.

Future Work

- **New libraries for better mesh generation will be investigated.**
(Re-design user interfaces and options with better mesh generation utilities)
- **Boundary conditions to describe air conditioning / heating will be improved.**
- **3D objects such as furniture, facilities or large machinery are needed to be created within the computational domain when those have an influence on the flow pattern.**
- **Radiative transport through window or light will be considered.**
- **Multi species gas flow and particle transport will be involved to simulate air contamination.**

Thank you

(Authors acknowledged financial support from KISTI and Ministry of Science, ICT and Future Planning.)

