



Description of computer simulated persons (CSP) for simulating local airflow and personal exposure: how simple is too simple?

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Background

What are considered and not considered in CSP?

- It blocks airflow (✓)
- It generates heat (✓)
- It generates pollutants (✓×)
- It breathes (?)
- It moves (×)



Background

What are the main purpose of CSP?

- Local comfort (airflow and temperature)
- Local pollutant exposure
- Room airflow
- Room pollutant dispersion



Background

How does CSP interact with different ventilation types?

- Natural ventilation
- Mechanical ventilation
 - * Mixing
 - * Displacement
 - * Personal
- Hybrid ventilation



Objective

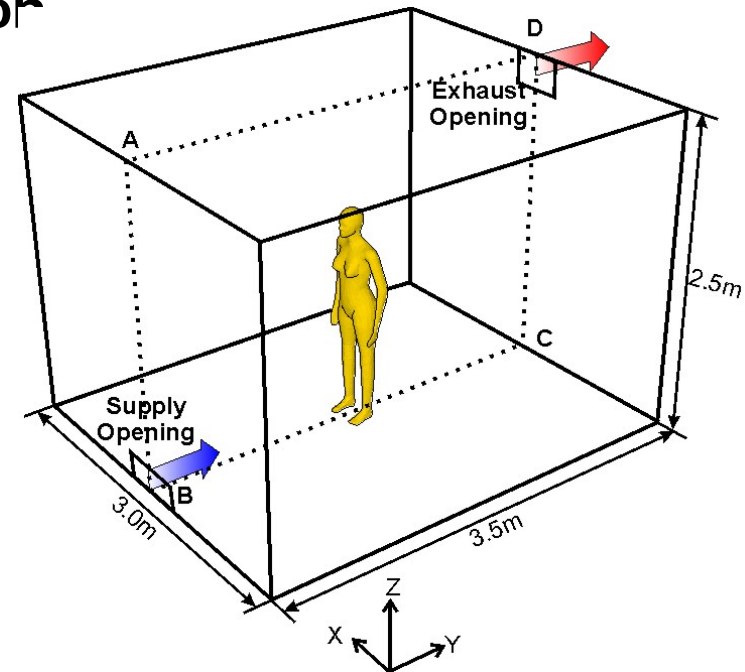
- **Study quantitatively how the simplified CSP affect local temperature and pollutant distribution.**
- **Provide recommendations on when and how to simplify CSP**

Approach

■ Benchmark Experiments (Nielsen et al., 2003)

❖ Displacement Ventilation

- (1) Room Size: 3.0m X 3.5m X 2.5m
- (2) Inlet: (a) Velocity: 0.182m/s
(b) Size: 0.4m X 0.2m
(c) Temperature: 21.8 C
- (3) Outlet: 0.3 X 0.3m
- (4) Manikin: 76W (Area: 1.471m²,
51.6W/m²)



Approach

■ Benchmark Experiments

❖ Mixing Ventilation

(1) Room Size: 1.2m X 2.44m X 2.46m

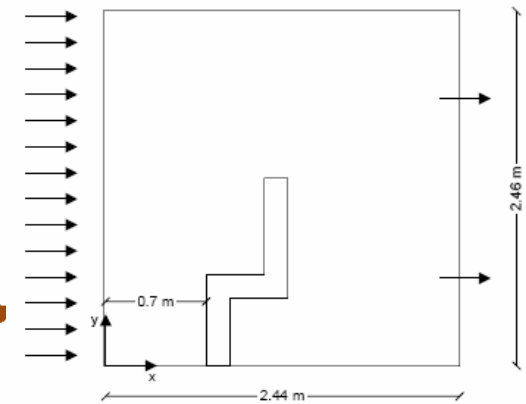
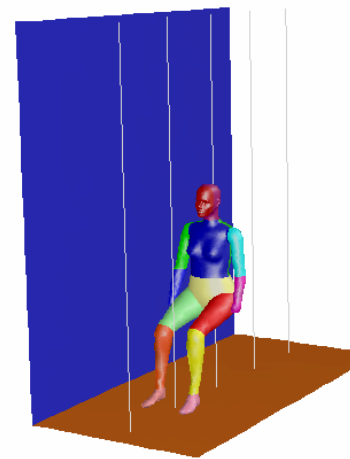
(2) Inlet: (a) Velocity: 0.5m/s

(b) Size: 1.2m X 2.46m

(c) Temperature: 22 C

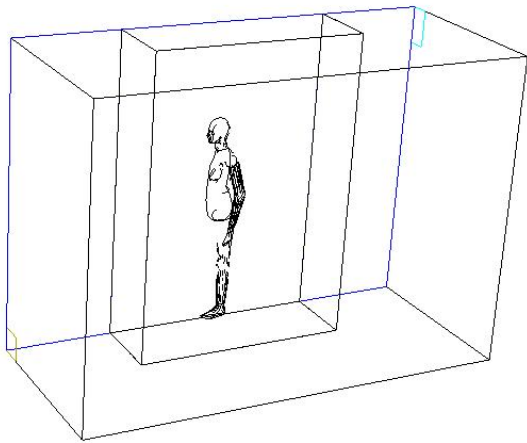
(3) Outlet: D=0.25m X2

(4) Manikin: 76W

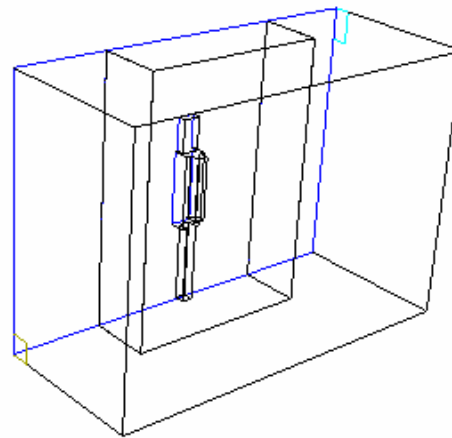


Approach

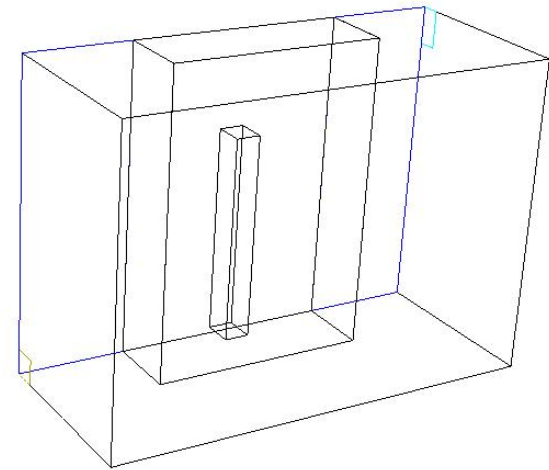
- Compare different CSPs (displacement ventilation)



Case 1 (human like)



Case 2 (simple manikin)

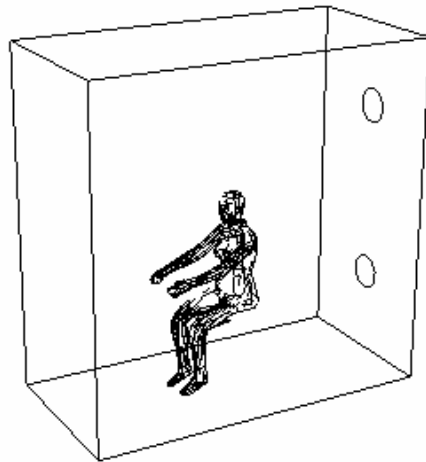


Case 3 (rectangular)

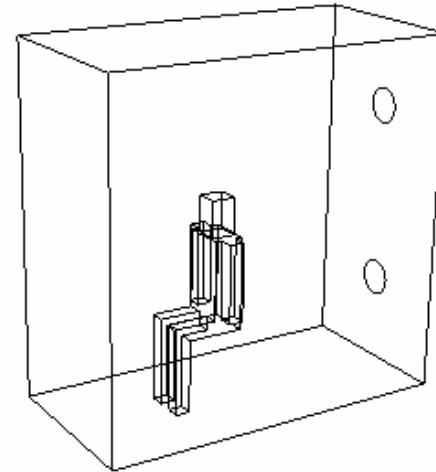


Approach

- **Compare different CSPs (mixing ventilation)**



Case 1 (human like)



Case 2 (simple manikin)



Approach

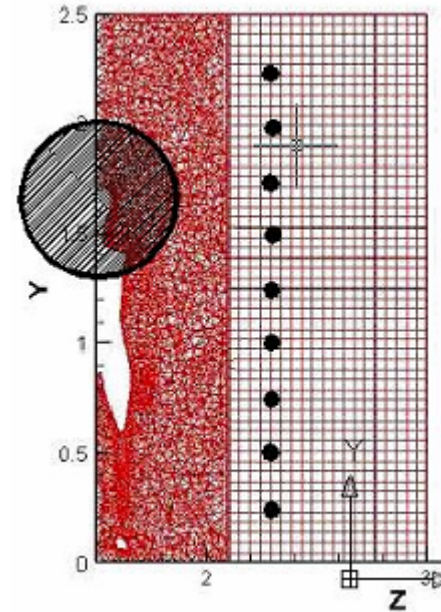
- **Items of comparison**

- Condition I: Pollutant is associated with heat source (from person)
- Condition II: Pollutant is not associated with heat source (from floor)

Items: (1) Temperature at respiratory area
(2) Temperature far away from manikin
(2) Concentration at respiratory area
(4) Concentration far away from manikin

Approach

- **Respiratory area**
A sphere around nose
 $r=0.35\text{m}$ ($dT/dx,y,z < 1 \text{ oC/m}$)
- **The area far away from manikin**



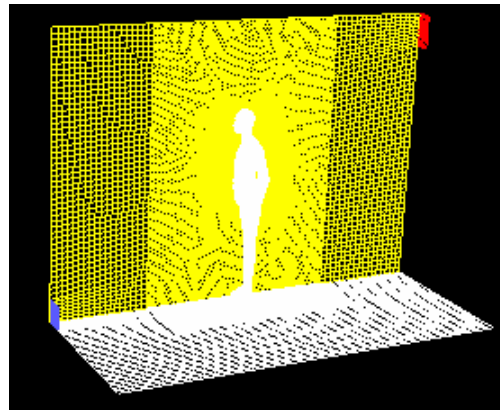
Approach

- **Grid and turbulence models**

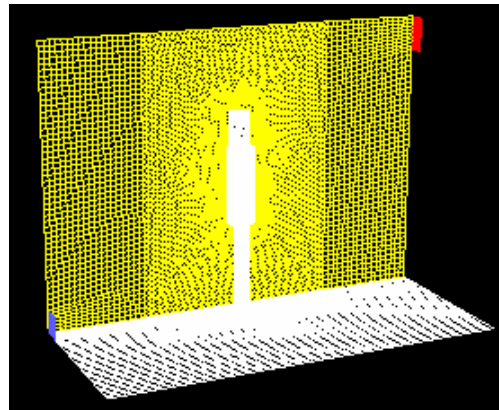
- **Displacement Ventilation**

Model: RNG K-e Model

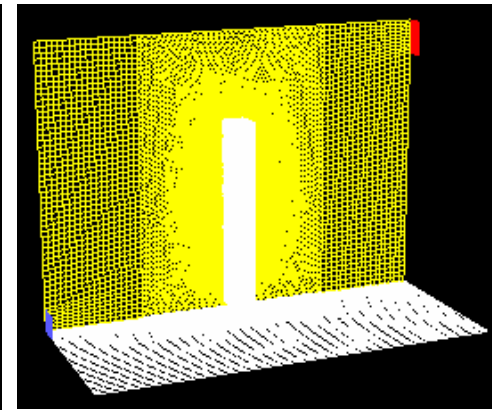
Grid: Structured (outer zone) and unstructured (inner zone)



Real manikin



Simple manikin



Rectangular manikin



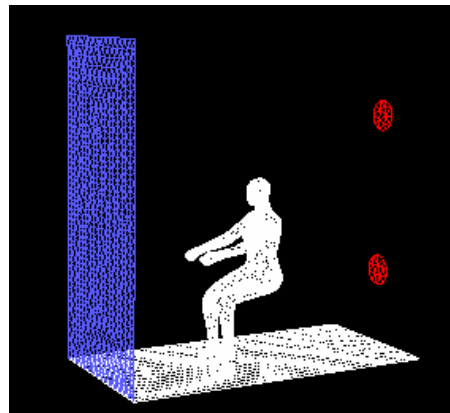
Approach

- **Grid and turbulence models**

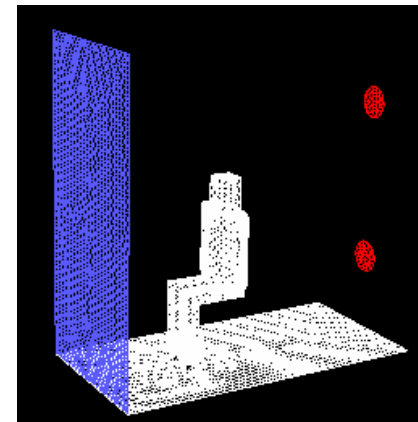
- **Mixing Ventilation**

Model: RNG K-e Model

Grid: unstructured



Real manikin



Simple manikin



Approach

- **How to define error?**
 - The purpose of our research is to determine the relative error due to simplified manikin. Therefore we assume the detailed manikin as baseline case.
 - Define error at far away area:

$$\bar{T}_{error} = \frac{\sum(\bar{T}_i - \bar{T}_{i\text{detail}})}{n\bar{T}_{i\text{detail}}} \quad \bar{C}_{error} = \frac{\sum(\bar{C}_i - \bar{C}_{i\text{detail}})}{n\bar{C}_{i\text{detail}}}$$

- Define error at respiratory area:

$$\bar{T}_{error} = \frac{(\bar{T}_{average} - \bar{T}_{average\text{-detail}})}{\bar{T}_{average\text{-detail}}} \quad \bar{C}_{error} = \frac{(\bar{C}_{average} - \bar{C}_{average\text{-detail}})}{\bar{C}_{average\text{-detail}}}$$

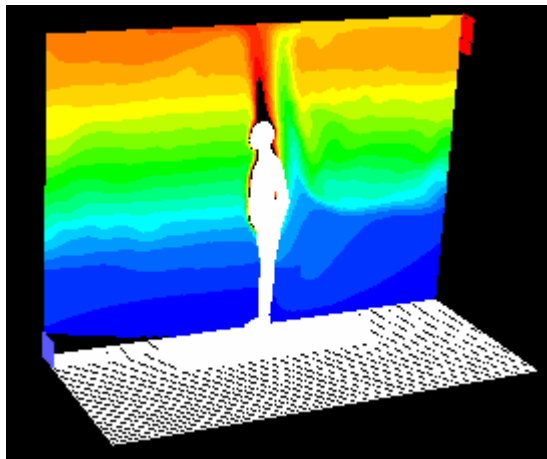
Note:

$$\bar{T} = \frac{T - T_{\text{supply}}}{T_{\text{out}} - T_{\text{supply}}} \quad \bar{C} = \frac{C}{C_{\text{out}}}$$

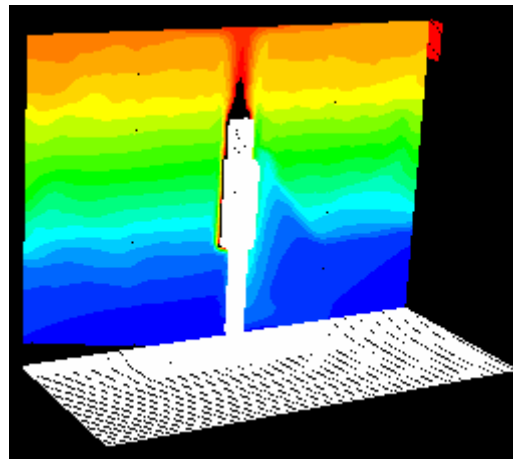
Results & Discussion

- Displacement Ventilation (Active pollutant)

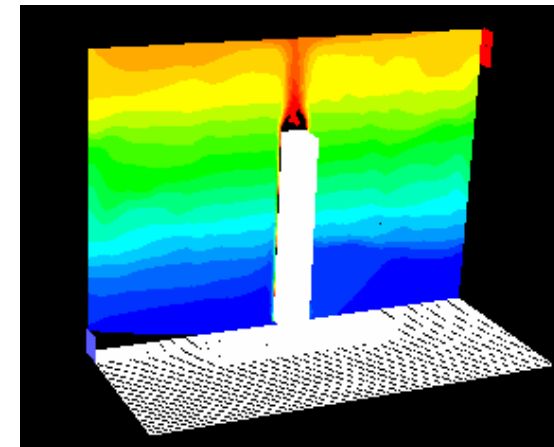
- Result



Temperature distribution
(detailed manikin)



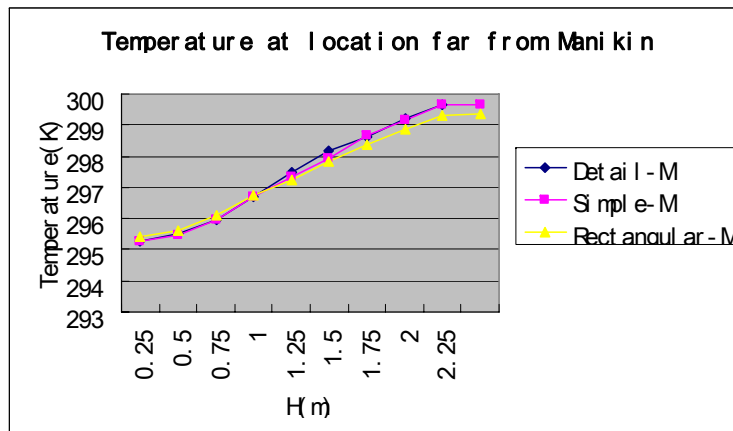
Temperature distribution
(simple manikin)



Temperature distribution
(rectangular manikin)

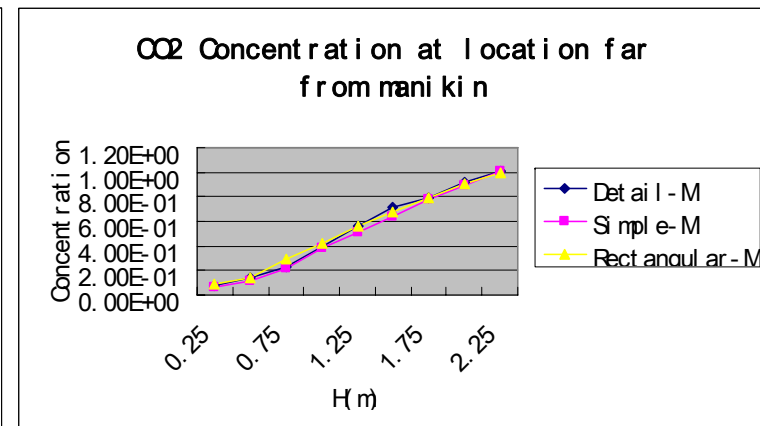
Results & Discussion

- Displacement Ventilation (Active pollutant)
 - The location far away from manikin



Simple-M: T-error=3.8%

Rectangular-M: T-error=7.6%



Simple-M: C-error=7.4%

Rectangular-M: C-error=7.7%



Results & Discussion

- **Displacement Ventilation (Active pollutant)**
 - **Respiratory area**

Type	T-average	C-average	Tout	Cout
Detail	0.911713	9.65E-01	1	1
Simple	1.060033	1.15E+00	1	1
Rectangular	1.128843	1.31E+00	1	1

Simple-M: **T-error=16.3%**

Simple-M: **C-error=19.0%**

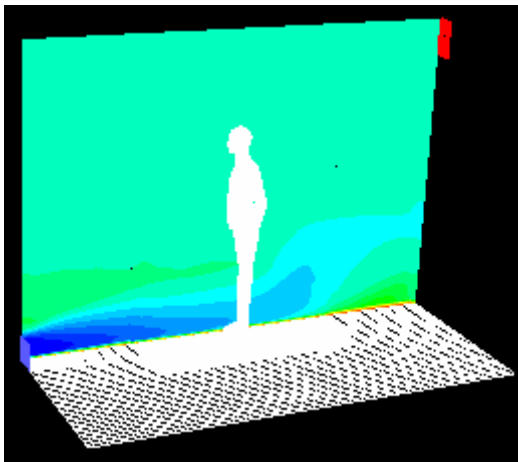
Rectangular-M: **T-error=23.8%**

Rectangular-M: **C-error=35.7%**

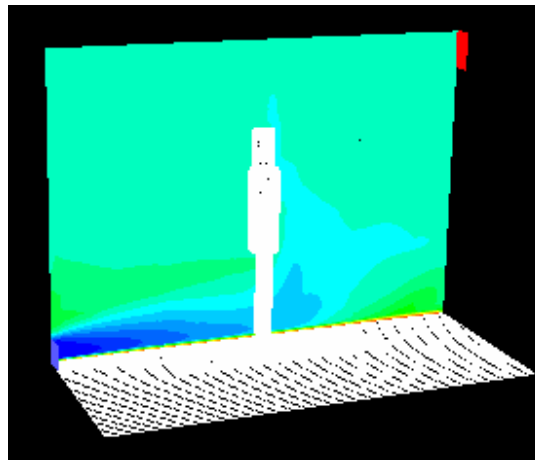
Results & Discussion

- Displacement Ventilation (Passive pollutant)

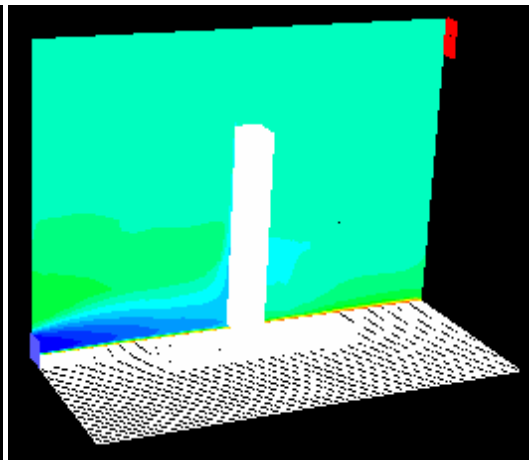
- Result



Concentration distribution
(detail manikin)



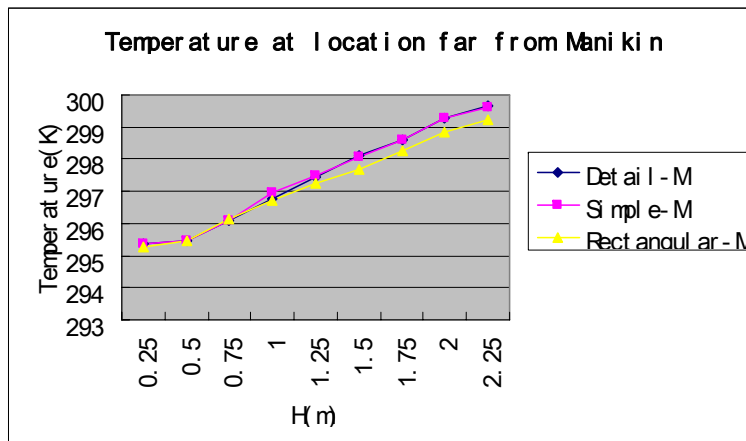
Concentration distribution
(simple manikin)



Concentration distribution
(rectangular manikin)

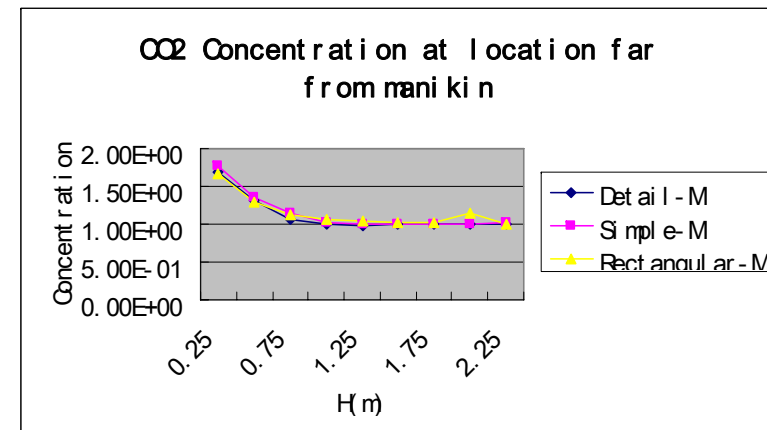
Results & Discussion

- Displacement Ventilation (Passive pollutant)
 - The location far away from manikin



Simple-M: T-error=3.5%

Rectangular-M: T-error=8.9%



Simple-M: C-error=2.6%

Rectangular-M: C-error=4.6%



Results & Discussion

- Displacement Ventilation (Passive pollutant)
 - Respiratory area

Type	T-average	C-average	Tout	Cout
Detail	0.916765	9.97E-01	1	1.00E+00
Simple	1.062824	1.00E+00	1	1.00E+00
Rectangular	1.126347	1.01E+00	1	1.00E+00

Simple-M: **T-error=15.9%**

Simple-M: **C-error=0.5%**

Rectangular-M: **T-error=22.9%**

Rectangular-M: **C-error=1.0%**



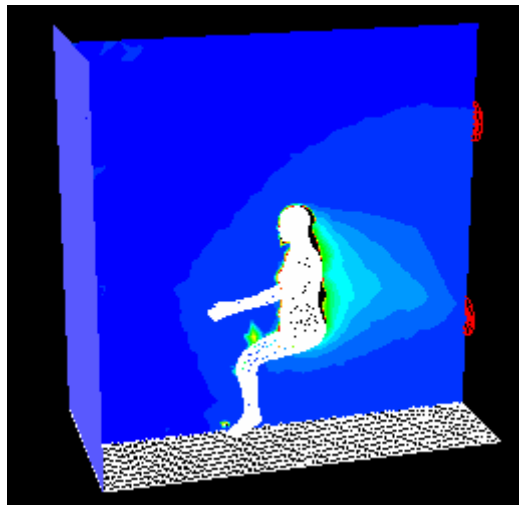
Results & Discussion

- **Discussion I: (Displacement Ventilation)**
- ❖ **T-error:**
 - ✓ Simple Manikin and Rectangular Manikin cause small error (<10%) at points far away from manikin. Both produce large errors (15~25%) at respiratory area because their heat source distribution are different than detailed manikin.
- ❖ **C-error:**
 - ✓ For active source, Simple Manikin and Rectangular Manikin cause small errors (<10%) at points far away from manikin. But they cause large errors (20~40%) at respiratory area.
 - ✓ For passive source, both Simple Manikin and Rectangular Manikin cause small errors (<5%).

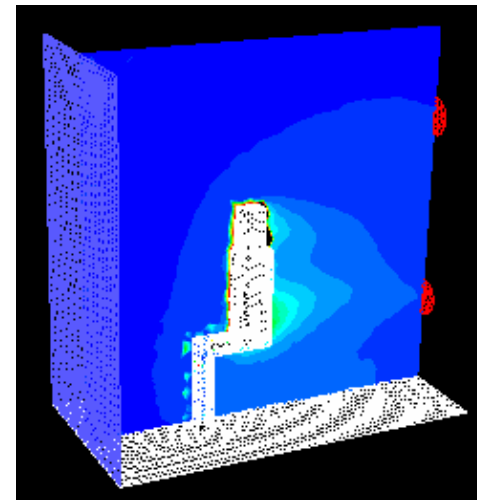
Results & Discussion

- **Mixing Ventilation (Active pollutant)**

- **Result**



Temperature distribution
(detailed manikin)



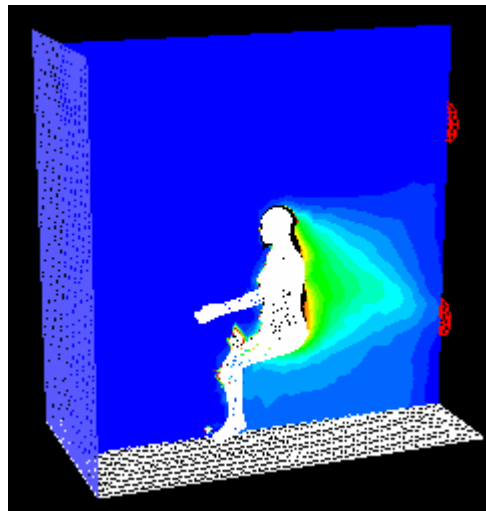
Temperature distribution (simple
manikin)



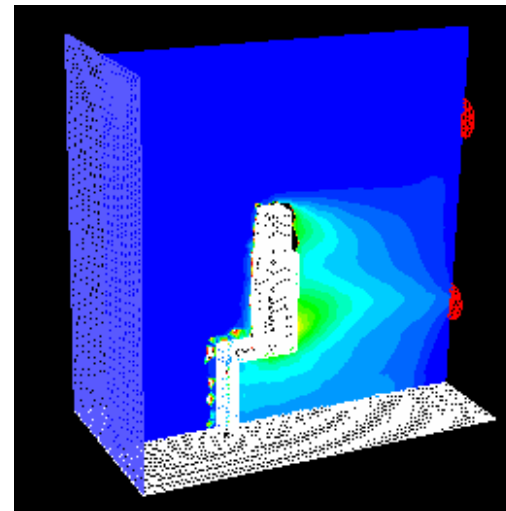
Results & Discussion

- **Mixing Ventilation (Active pollutant)**

- **Result**



Concentration distribution (detail manikin)



Concentration distribution (simple manikin)



Conclusions

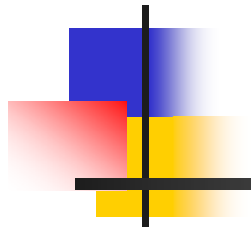
- When could we use simplified manikin?

	Normal Area			Respiratory Area		
	<u>Mv>>B</u>	<u>Mv~B</u>	<u>Mv<<B</u>	<u>Mv>>B</u>	<u>Mv~B</u>	<u>Mv<<B</u>
Active source	T-yes	T-yes	T-yes	T-no	T-no	T-no
	C-yes	C-yes	C-yes	C-no	C-no	C-no
Passive Source	T-yes	T-yes	T-yes	T-no	T-no	T-no
	C-yes	C-yes	C-yes	C-yes	C-yes	C-yes



Conclusions

- How to simplify manikin?
 - ✓ **Total heat the same (*****)**
 - ✓ **Heat distribution similar (****)**
Make heat distribution (head, torso+arms, legs) as similar to real person as possible.
 - ✓ **Shape and total surface area similar (***)**
Especially make the dimension of the manikin head similar to real person.



The End

Thanks