# S. Kato LAB.

## [Control of air environment in sustainable society]

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**Engineering of architecture and urban environment**

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## Time reversal simulation for identifying the diffusion source of toxic gas in urban area

The methodology for identifying the diffusion source is investigated against the backdrop of the increasing possibility of dispersion of toxic matter in an unknown place in an urban area.

By using the concentration field given on a specific time as the initial condition, negative time dependent convective diffusion equation were managed to solve.

When Reynolds average was operated to the equation and especially when the velocity field is constant, the diffusion term which include the modeled convective term need to solve counter gradient transport, which often cause to numerical instability. In order to ease up the instability, the filtering operation was applied in a 3D space.

The filtering trial were approached to both concentration and diffusion flux.

As a result, the equation can be solved, in particular, the latter method showed a better convergence of concentration to a source location.

When the case obstacles exist, the results is still plausible and the availability of detecting diffusion source is proved.

○time reversal convective diffusion equation

$$\frac{\partial C}{\partial t} - U_i \frac{\partial C}{\partial x_i} = -\frac{\partial}{\partial x_i}\left(\frac{\nu_t}{\sigma_3}\frac{\partial C}{\partial x_i}\right)$$

Counter gradient transport

○filtering

$$\overline{F}(x) = \int_{-\infty}^{\infty} G(r)F(x-r)dr$$

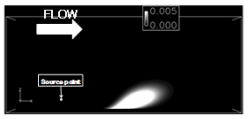
$$G(r) = \sqrt{\frac{6}{\pi\Delta^2}}\exp\frac{-6r^2}{\Delta^2}$$ Gaussian filter

○objectives of filtering

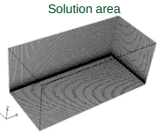
$$F_i = C_i$$ Concentration

$$F_i = -\langle uic \rangle = \frac{\nu_t}{\sigma_3}\frac{\partial C}{\partial x_i}$$ Diffusion flux

○ Initial condition

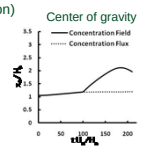



Solution area

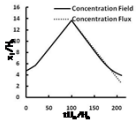


○ Reversal calculation (filtering the concentration)

Center of gravity


○Reversal calculation (filtering the diffusion flux)


## Periodic energy simulation considering the time dependent and non-uniform indoor temperature field

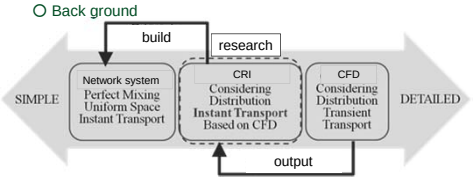
Although the non-uniform air conditioning such as task ambient or personal air conditioning is often applied to indoor space, the energy simulation model based on network system has taken no account of non-uniformity of indoor temperature distribution.

In order to revise the problem, the methodology to integrate the network energy simulation model and the estimated effect of indoor heat transport was suggested. In order to take account the effect of heat transport, Contribution Ratio of Indoor climate (CRI) is applied, which is calculated by computational fluid dynamics (CFD).

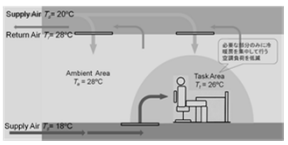
CRI is the characteristic value of the discretized spaces. It represents the appreciation rate of temperature when the sources generate unit amount of heat. When the linearity between the appreciation rate and the sources generation was supposed, and when the independency between each sources were supposed, the appreciation rate of temperature may be expressed by 1 dimensional polynomial of each CRI.

By adding this appreciation rate to the uniform temperature which is calculated by energy simulation model based on network system (say, TRNSYS, HASP/ACLD), the coupling between network system and the effect of indoor heat transport will become possible without consuming the time for calculating CFD.

○ Back ground




○ Subject of research




○ Definition of CRI（Numerical simulation）

$${}^{u}CRI_m(x_i) = \frac{\Delta^u\theta_m(x_i)}{Q_m}$$

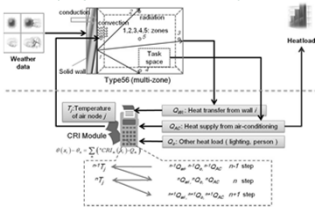
$\Delta^u\theta_m(x_i)$ Temperature increase in $(x_i)$ by heat source $m$

$Q_m$ Amount of heat from source $m$

○ Temperature prediction by CRI

$$\theta(x_i) - \theta_0 = \sum_m \left({}^{u}CRI_m(x_i)\cdot Q_m\right)$$ Convolution of all heat source

○ Coupling of CRI and network system




## The controlling method of indoor environment in office building considering the circadian rhythm

Light, thermal, acoustic and indoor air environment in a business office are designed dull uniformly. It may disturb human circadian rhythm, consequently, may cause to the detraction of human psychology, physiology and intellectual productivity.

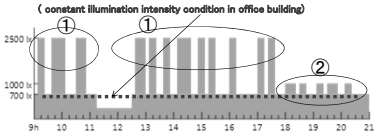
The methods to control the light and thermal environment which preferably sustain the circadian rhythm are investigated.

The light environment was set to follow the natural light. Illumination intensity can be set higher than normal when workers want in a daytime. After 6:00PM, the maximum intensity is restricted to be lower. The effect of the control was evaluated by the dominancy of sympathetic nerve and parasympathetic nerve.

The thermal condition is set by considering the deep body temperature. Indoor air temperature in the afternoon was set 3 degrees higher than in the morning. The effect to adjust the circadian rhythm was aimed. The effect was evaluated by the temporal response of deep body temperature. As a intermediate result, the possibility which these regulation is affect to maintain the circadian rhythm was proved.

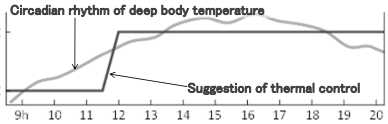
For the next step, as for the light, the influence of wave length of blue light on the rhythm will be considered. As for the thermal condition, the air blower for individual usage which combines the temperature regulation and the thermal comfort will be considered.

○ Light control considering circadian rhythm

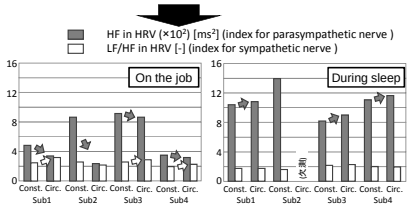



① Depend on demand (after 20min, it decays to 700lx)
② Restriction of maximum (after 18:00, 1000lx maximum)

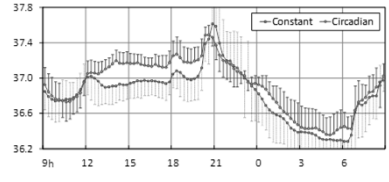
○ Thermal control considering circadian rhythm




Considering the deep body temperature, indoor air temperature in the afternoon was set 3 degrees higher than in the morning (vertical axis only shows the thermal control)




The sympathetic nerves became dominant on the job
The parasympathetic nerves became dominant during sleep




The deep body temperature increased in the afternoon
The increase of amplitude and advance in phase was observed