Integrating CFD, VR, AR and BIM for Design Feedback in a Design Process

An Experimental Study

Nov. 20, 2015

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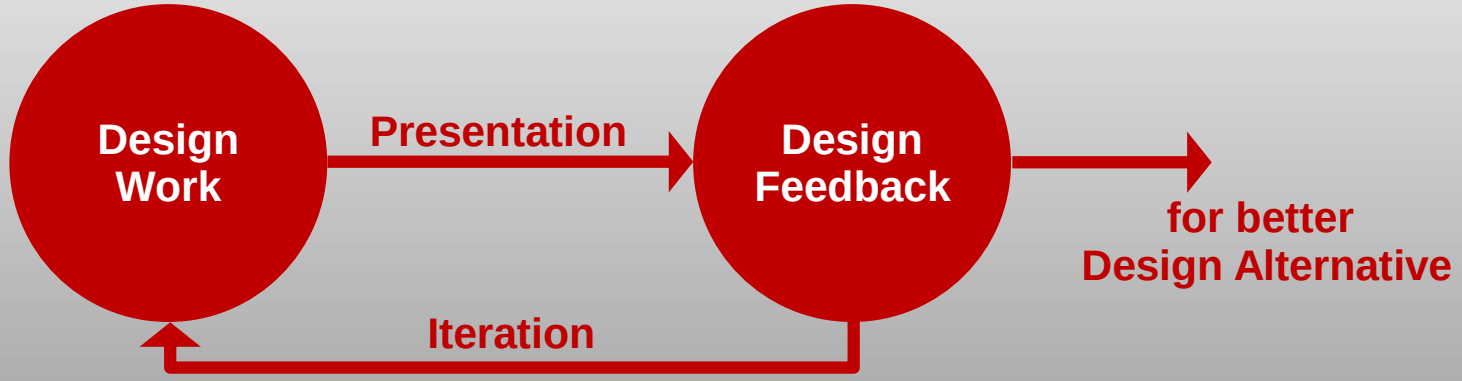
Revision of our presentation in the 33rd eCAADe, Vienna, 2015

Motivation

- To improve indoor thermal environment, it is necessary to do more with less in a design process, forecasting and consensus building among clients, architects and engineers by experiment and numerical simulation from the design stage have become essential.
- Rapid advances in software and hardware allow design feedback to be generated on novel design alternatives, rather than relying on results and experiences based on past designs.
- The concept, - that faster simulations allow feedback on new design alternatives between architects and engineers - has not been fully discussed.

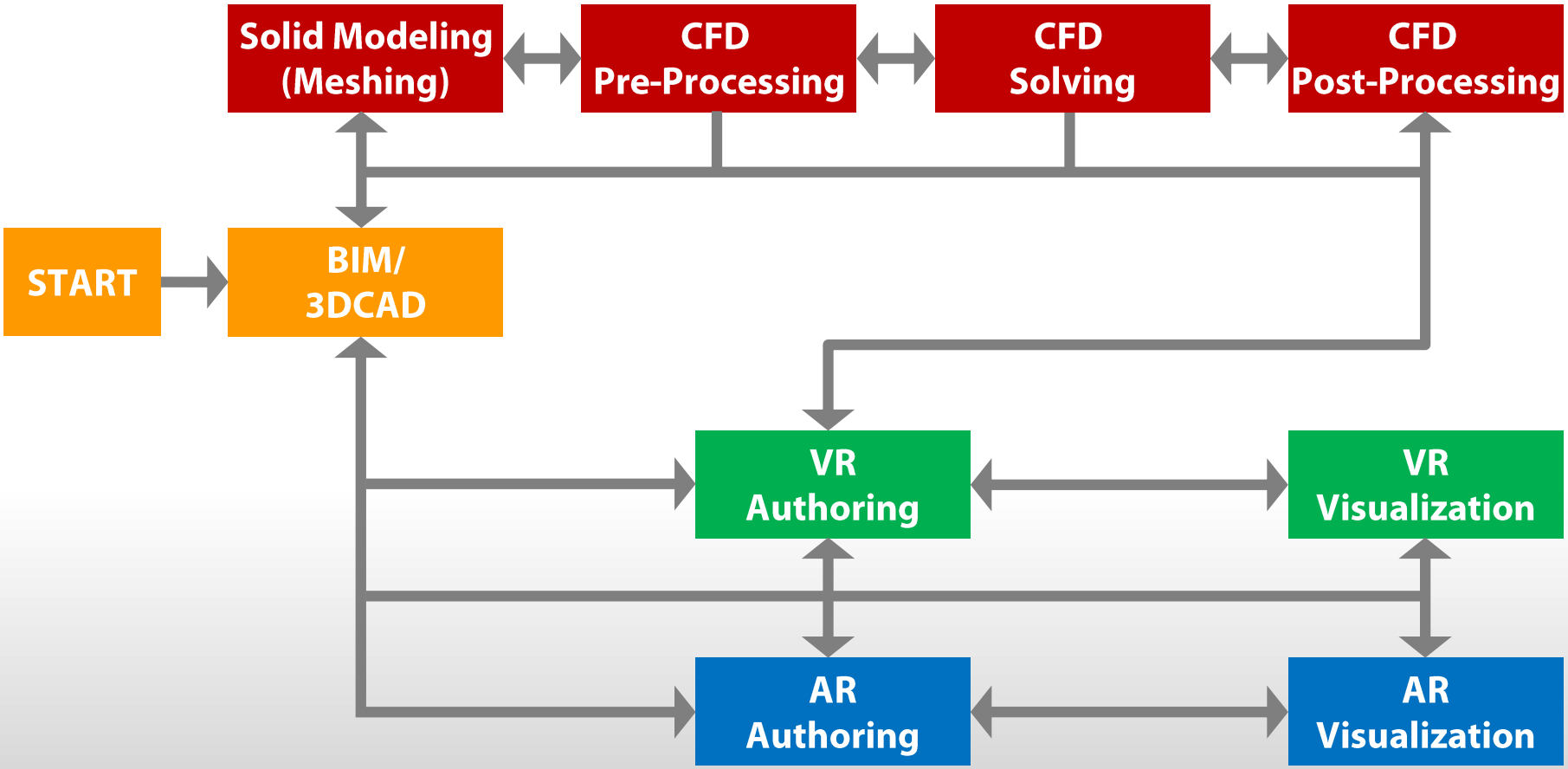


Objective

- This study presents an integrated design tool which consists of:
  - ✓ Computational Fluid Dynamics (CFD)
  - ✓ Virtual Reality (VR)
  - ✓ Augmented Reality (AR)
  - ✓ Building Information Modeling (BIM)
- The tool was applied to the problems of an actual housing design process.
- Both the content of design feedback on design problems revealed through simulations in the project, and the features in the feedback process were discussed.

Contents

Integrating CFD, VR, AR and BIM

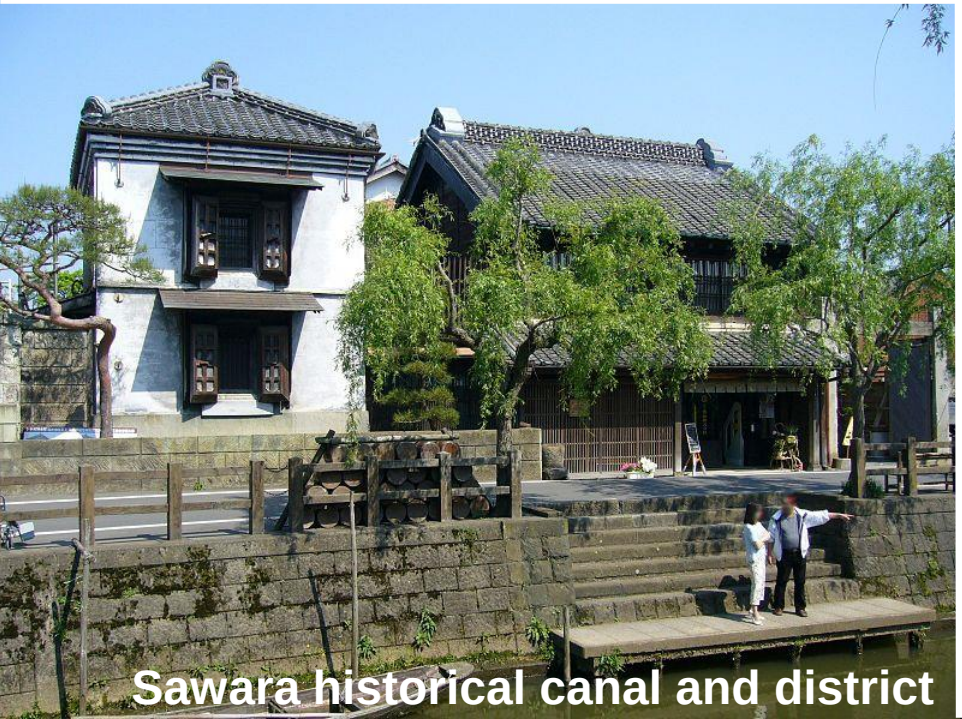


- This figure shows the entire integration process of CFD, VR, AR and BIM from modelling to visualization.
- Each step must be interactive to reflect the fact that design is always evolving, in response to a range of factors.

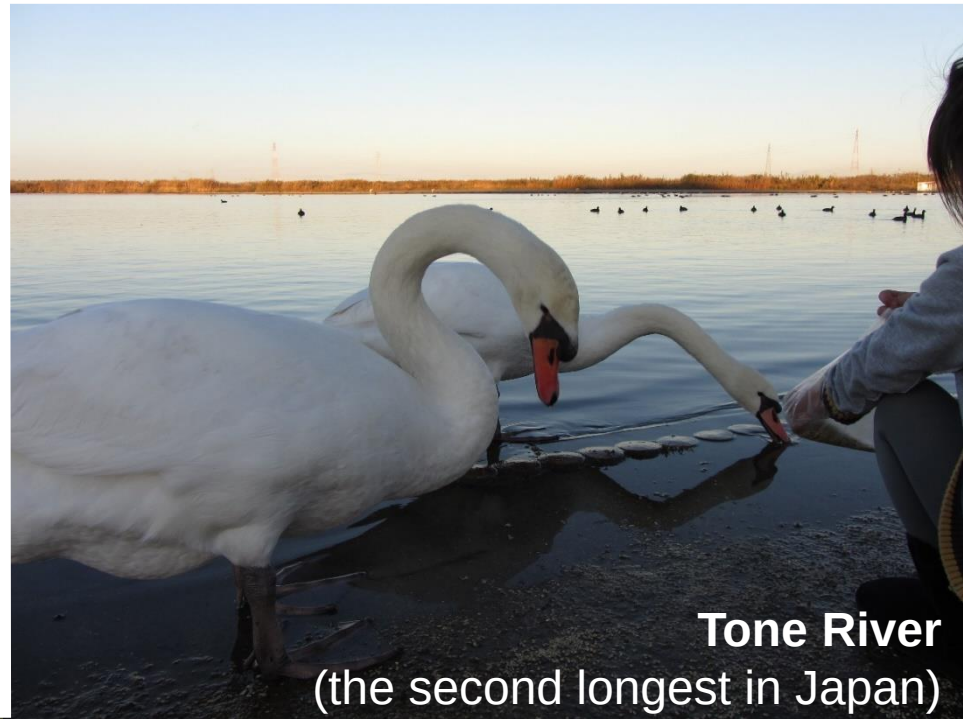
Contents

Itako Maekawa Iris Garden

Kashima Shrine



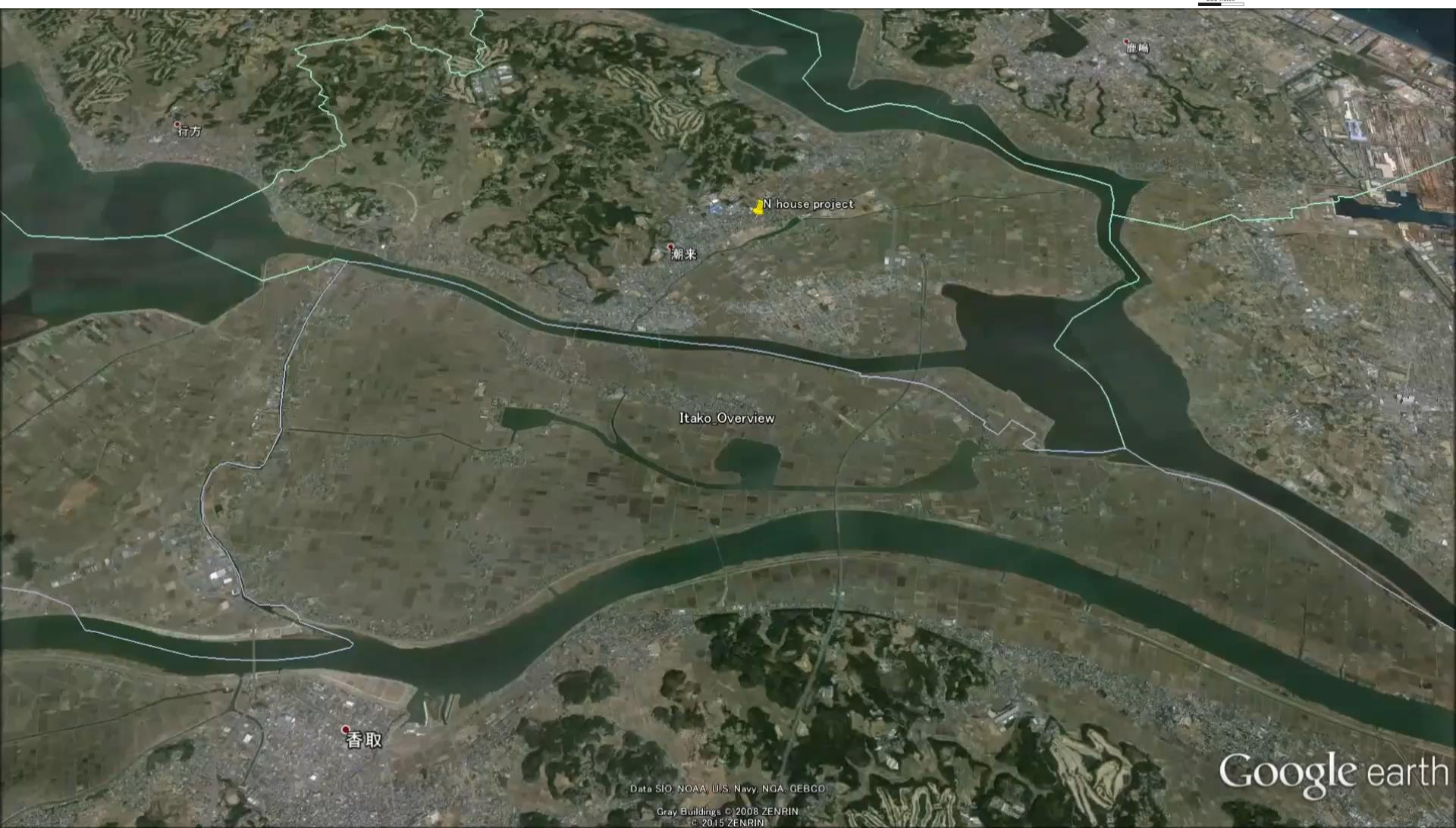
Sawara historical canal and district



Tone River
(the second longest in Japan)

Outline

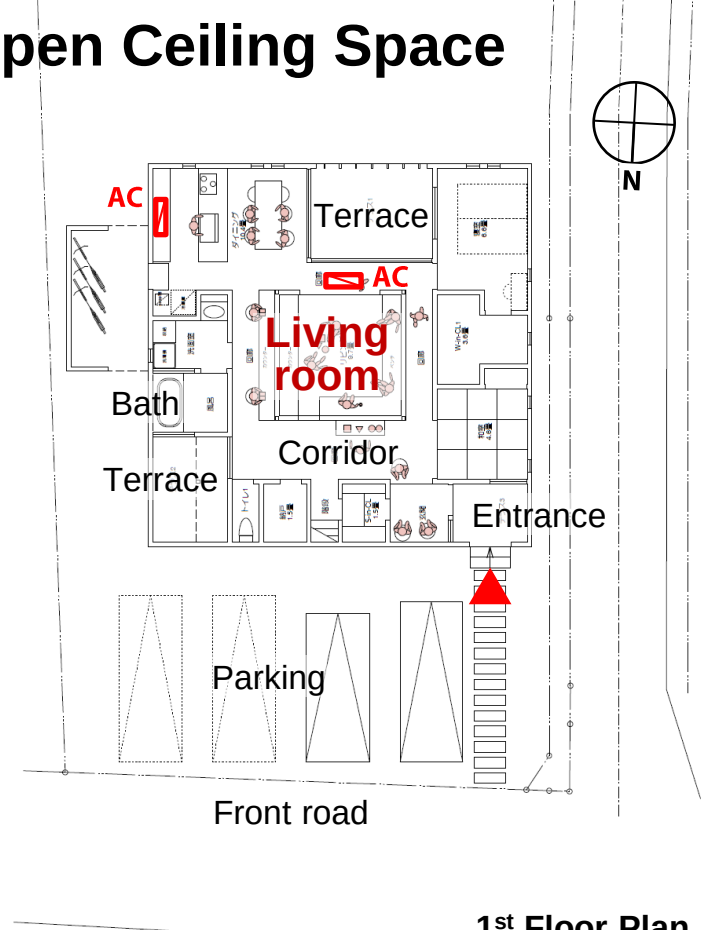
Site: Itako City, Ibaraki pref., Japan



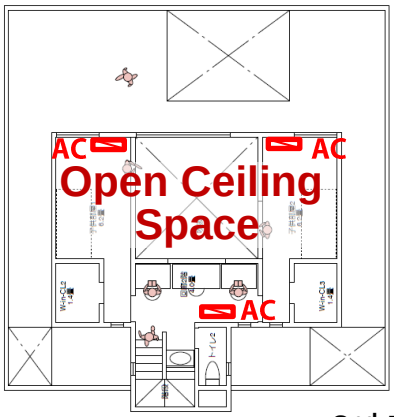
Outline

Site area: 401.73m²
Total floor area of two-story house: 135.46m²

Triple-Nested Design, Living Room with Open Ceiling Space



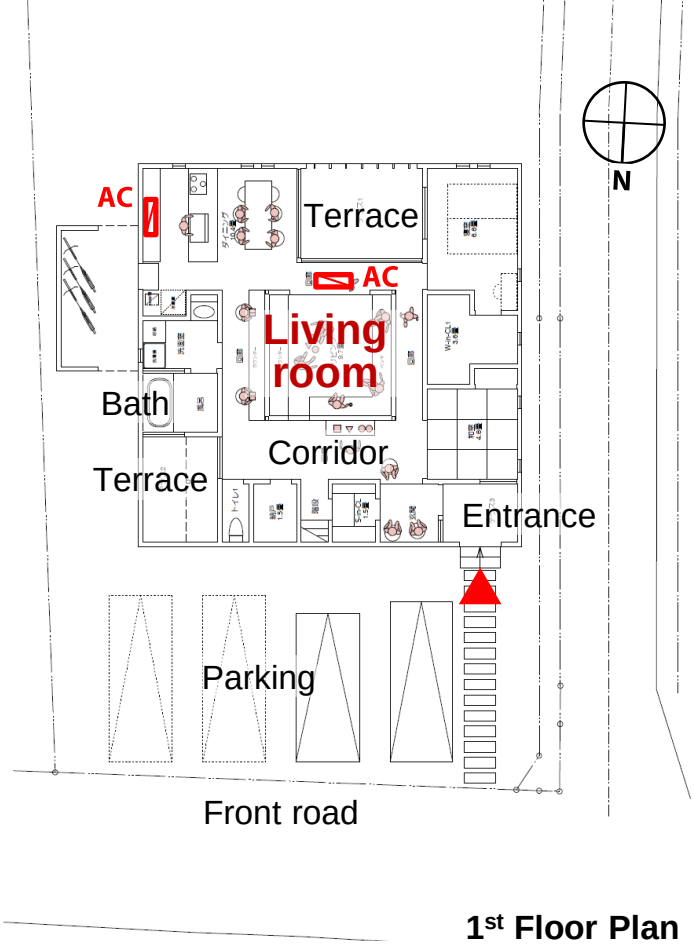
1st Floor Plan



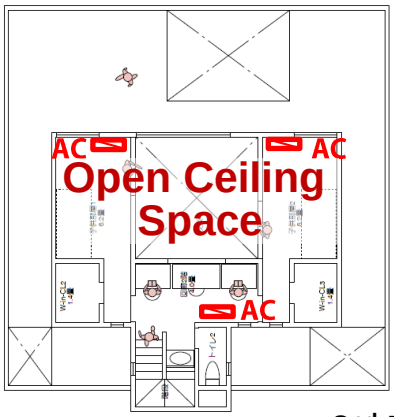
2nd Floor Plan

Design Challenges

1. An optimal thermal environment of the living room had to be achieved. This room had a open ceiling space, which connects with some rooms on the first floor, and with some rooms and stairs on the second floor.



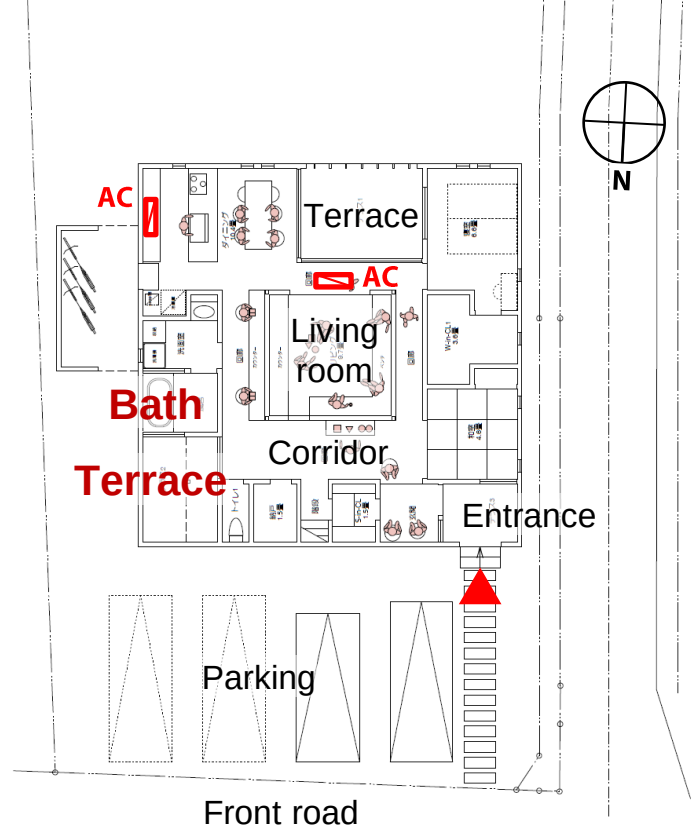
1st Floor Plan



2nd Floor Plan

Design Challenges

1. An optimal thermal environment of the living room had to be achieved. This room had a open ceiling space, which connects with some rooms on the first floor, and with some rooms and stairs on the second floor.
2. An outdoor terrace from which the client could look at sky from the bath was designed. It was necessary to solve privacy issues related to whether the client in the outdoor terrace bath was visible from other buildings.
3. Since the site was located in a traditional town, the width of the front road was narrow. The arrangement of the parking lot had to be considered.



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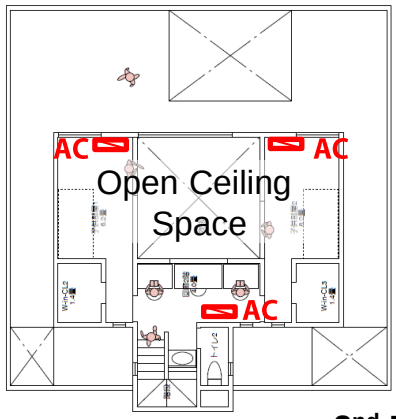

2nd Floor Plan

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CFD & VR

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VR

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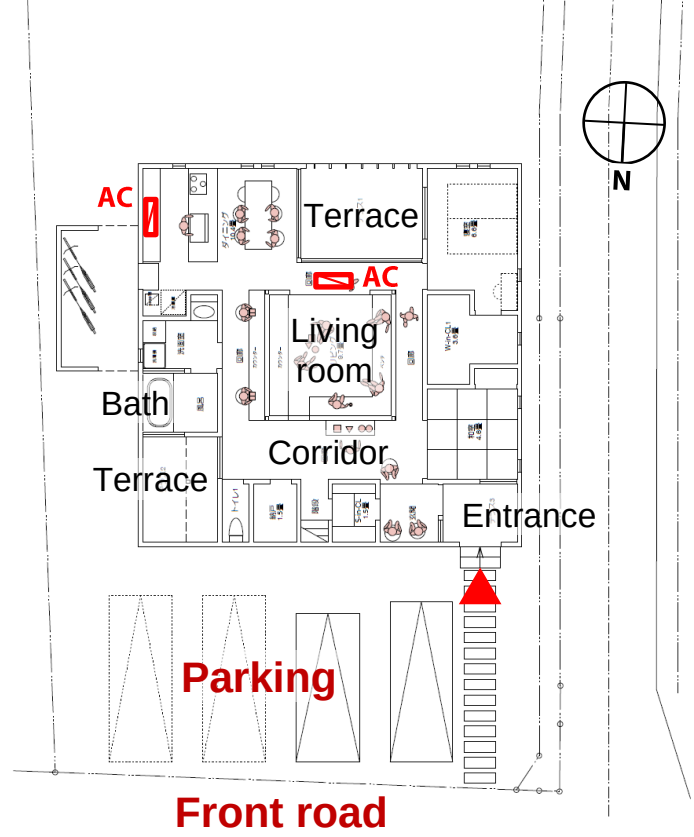
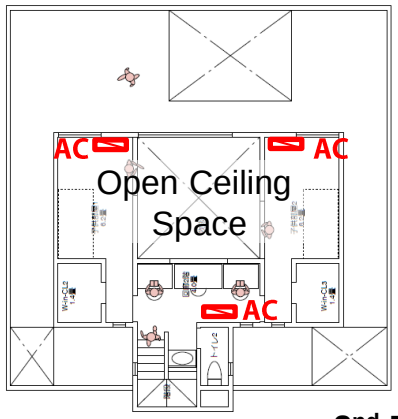
AR



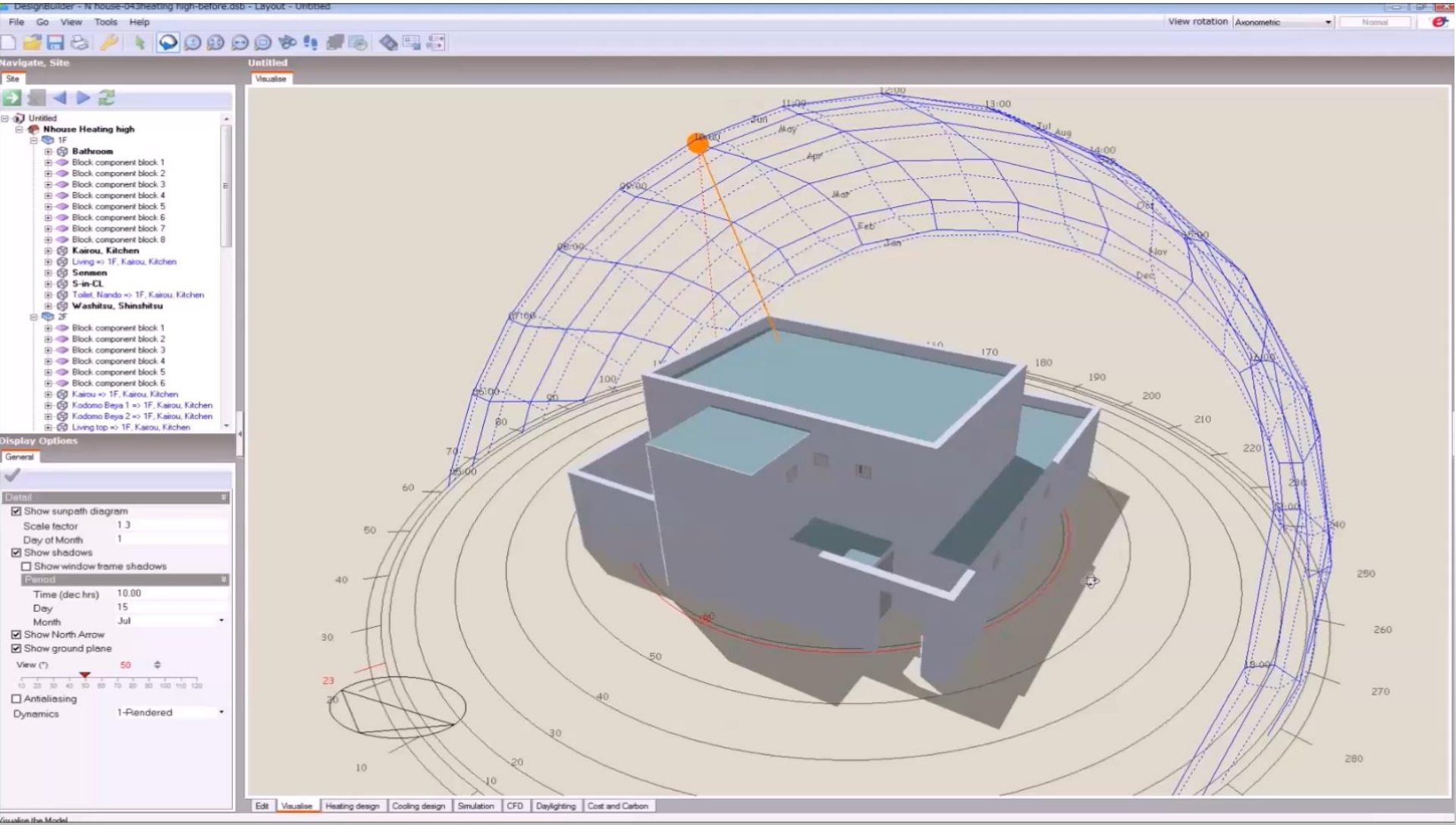
1st Floor Plan



2nd Floor Plan

Contents

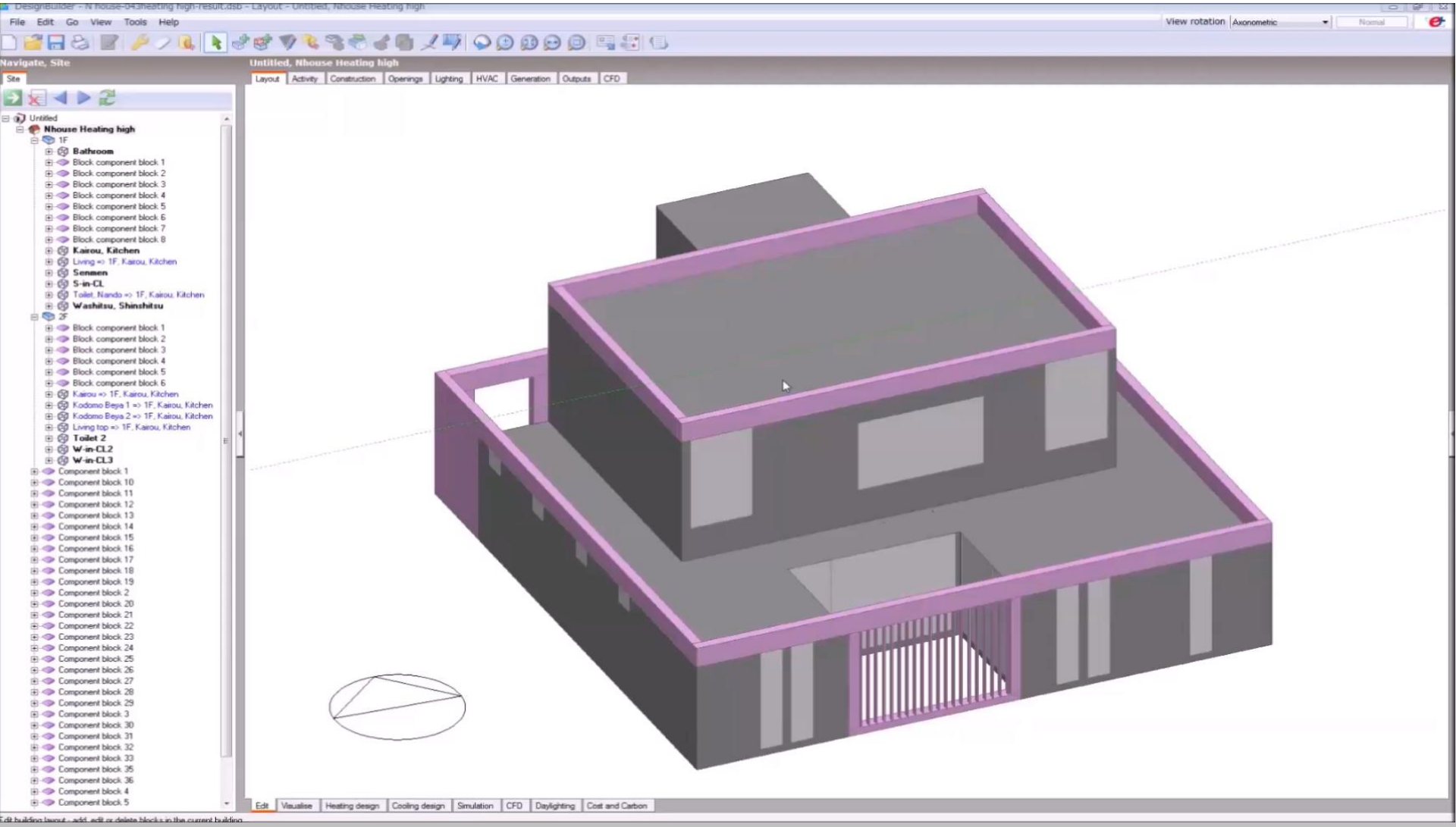
CFD Simulation (Pre-Processing)



- Location, Orientation
- Materials: wall, roof, flooring, glass, door
- HVAC (Heating, Ventilating, and Air conditioning)

DesignBuilder Engineering Pro 4.1 **X3**

CFD Simulation (Solving)



- Air-conditioning product
- Simulation periods

DesignBuilder Engineering Pro 4.1 **X3**

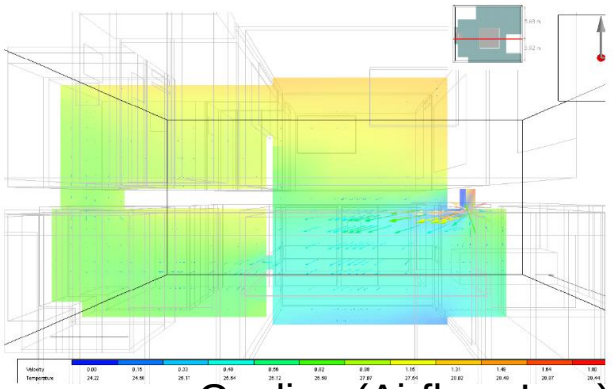
CFD Simulation (Initial Plan)

Summer

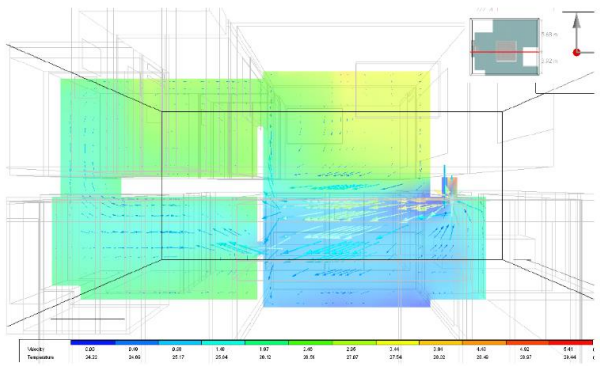
Date: Aug. 12, 16:00

Outside air temperature: 35 ℃

Airflow: high and low



Cooling (Airflow: Low)



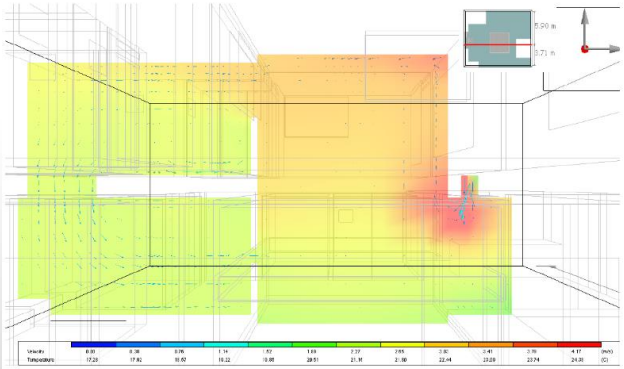
Cooling (Airflow: High)

Winter

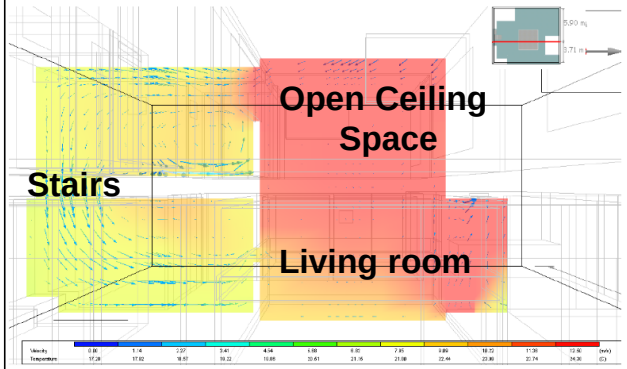
Date: Feb. 13, 16:00

Outside air temperature: 7 ℃

Airflow: high and low



Heating (Airflow: Low)



Heating (Airflow: High)

Result:

In winter, warm air from the air conditioning rose in the open ceiling space, and the occurrence of a downdraft was revealed on the stairs.

CFD Simulation (Design Feedback)

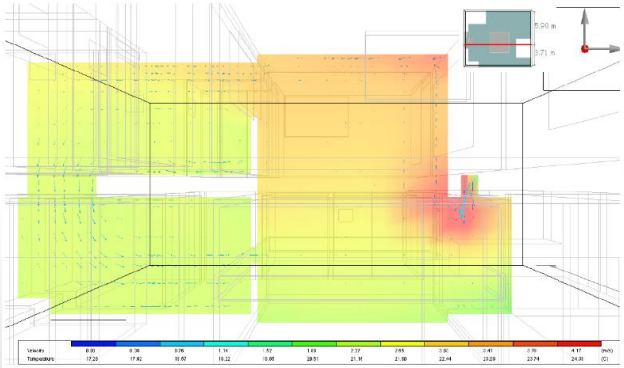
- A movable sliding door at the foot of the stairs was designed. The downdraft was suppressed, and the thermal environment was improved.
- The movable door was closed only when the heating was used. When the door was opened, the corridor space design remained attractive since this door was hidden behind the wall.

Winter

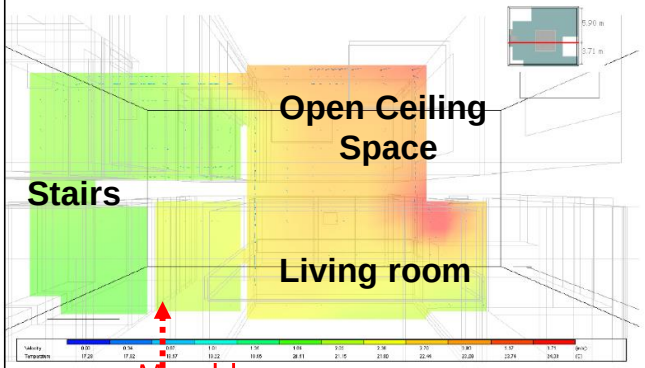
Date: Feb. 13, 16:00

Outside air temperature: 7 ℃

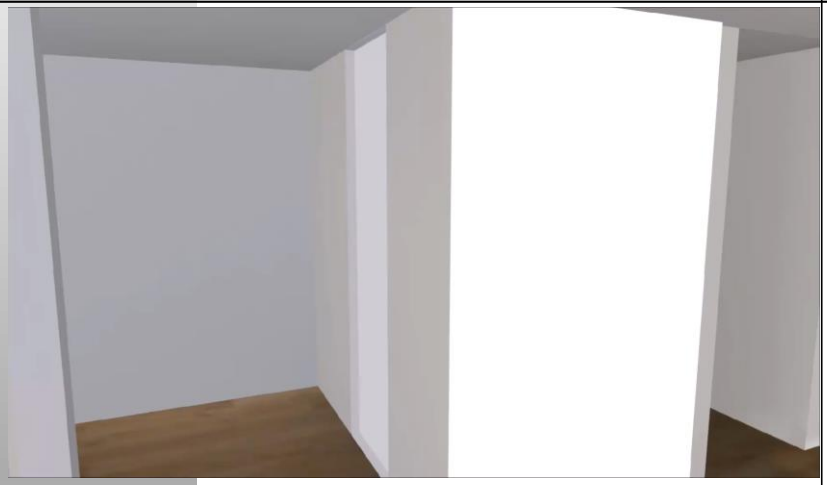
Airflow: low

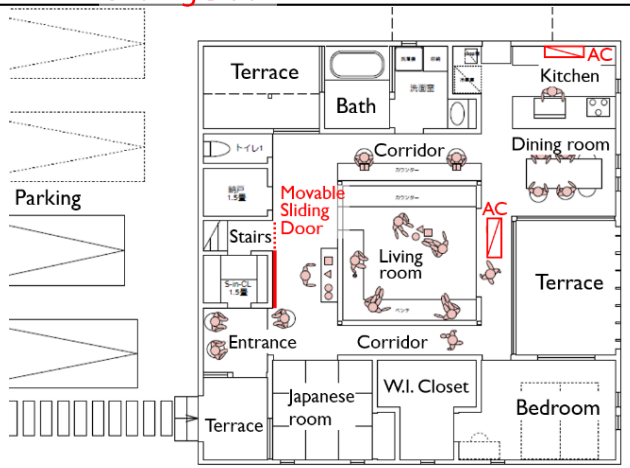


Initial Plan



Alternative Plan





VR Simulation

UC-win/Road ver.10 & VR-Cloud ver.6

- The designer studied and confirmed that the designed outdoor terrace of the bath was invisible from any of the buildings in the neighborhood using VR.
- After the designer explained this fact to the client, the client was relieved and agreement for the bath plan was obtained.

CFD simulations in the VR

Initial Plan

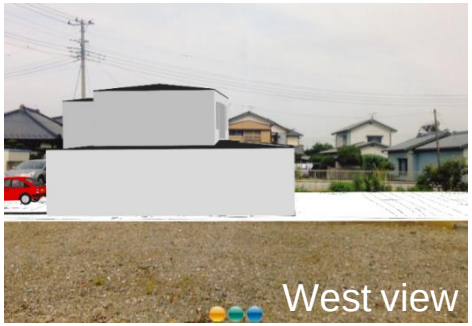
Alternative Plan

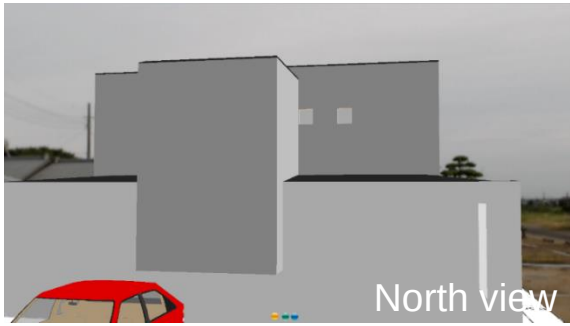
- By arranging the results of the CFD simulations in the VR, the thermal environment was visualized using arrows (as wind direction) and a color map (as temperature).
- This representation helped the client to understand the airflow more intuitively.
- A new problem was found that CFD simulator can not export the arrows and the color map information as vector data (Design Builder Engineering Pro 4.1).

AR Simulation

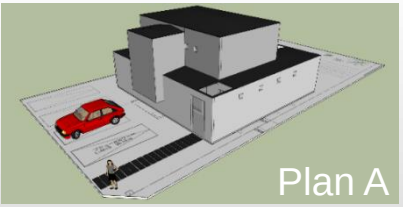
- For the car parking study, both the current live video and designed 3D model were superimposed by using a marker-less registration.
- The amount of detail in the image used for tracking was insufficient, and it is difficult to track to keep correct registration.

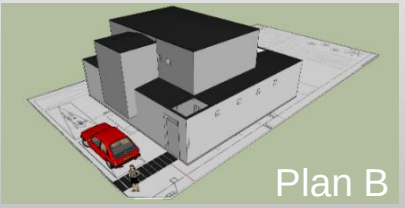
Images for image tracking

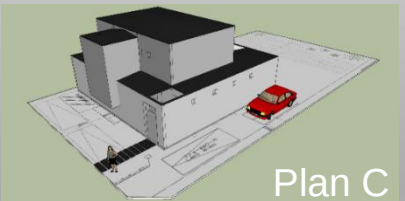




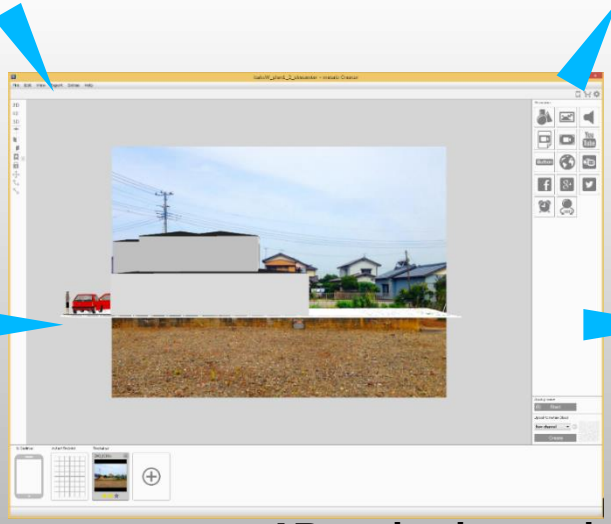
Results: AR screen capture







Alternatives



AR authoring tool
(Metaio Creator 3.5)

Design review by owners using AR and HMD

Contents

Conclusion

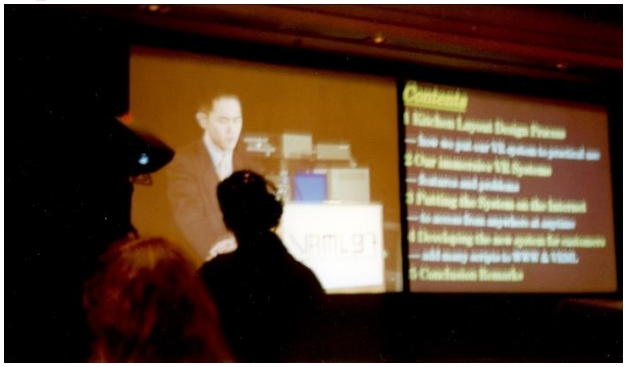
- This study presented an integrated design environment comprising CFD, VR, AR and BIM.
- The proposed system was applied to the challenges of a real housing design project, in collaboration with an architect and with engineers.
- Both the content of the feedback on design challenges revealed through simulations in the project, and the features of the feedback process itself, were analysed.

Future Work

- **CFD simulator** should export the arrows and the color map information as vector data to import VR/AR system seamlessly.
- The view angle of applied **AR-HMD** (Vizux WRAP 1200DXAR) was 35°, and the client commented that the view angle was too narrow. The authors start to apply other **AR-HMD** of wider view angle such as Oculus Rift DK2 + Ovrvision 1 (H: 90°, V: 75°).
- Temperature sensors etc. will be installed in the living room to measure the actual thermal environment and to verify the difference between the CFD simulation and actual sensed data.

VRML97 (1997)

2nd Symposium on the Virtual Reality Modeling Language
Monterey, CA



BTTF II (1985)

Practical use

- Bio-fuels
- Hoverboard
- Fingerprint Scanners
- Robotic Service Station
- Robotic Waste Disposal
- Wearable Weather Reports
- Rejuvenation Centers
- Holograms
- Scenery Screens
- Augmented reality headsets
- Automated Dog-Walker
- Indoor Gardens
- Wireless Faxes/Printers

2015 (Oct. 21, 4:29pm)

2045

Self-introduction:

Environmental Design and Information Technology Area

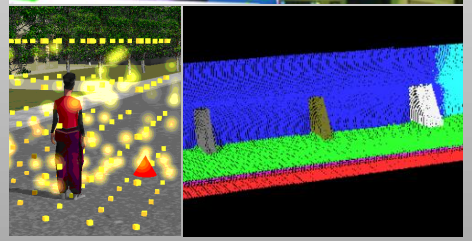
http://y-f-lab.jp
CV: http://goo.gl/dWeVv
fukuda@see.eng.osaka-u.ac.jp
Twitter | Facebook | LinkedIn
Research Gate etc.

Area Overview

Our laboratory develops new environmental design methodologies, which can organize the relationships of humans, artificial objects, and nature systematically, deploying advanced information and communication technologies (ICT) and creates new environment where ICT is embedded.

Members 2015

3 Faculties | **2** Researchers
7 Doctor Course Students (including 2 int'l students)
13 Master Course Students (including 6 int'l students)
4 Undergraduate Seniors | **4** Research Students (int'l)



Research Themes

1. Application of Augmented Reality and VR for Architecture and Urban Fields
2. Geometric Modeling Using Point Cloud Data of Laser Profile Scanner
3. Data Mining of Environmental Sensing for Energy Management
4. ICT for Developing Smart City etc.