TROLL RESEARCH STATION

Midterm presentation 13/3

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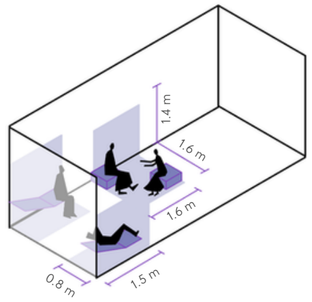
IAP Workshop
Q3 2026
Prof. Henriette Bier, Arwin Hidding, Lisa-Marie Mueller, Vera Laszlo

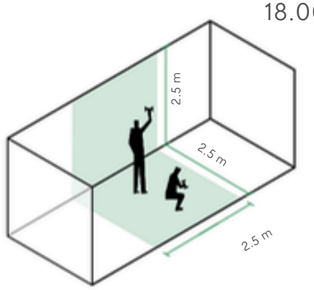
01 RESEARCH | ACTIVITY MAPPING



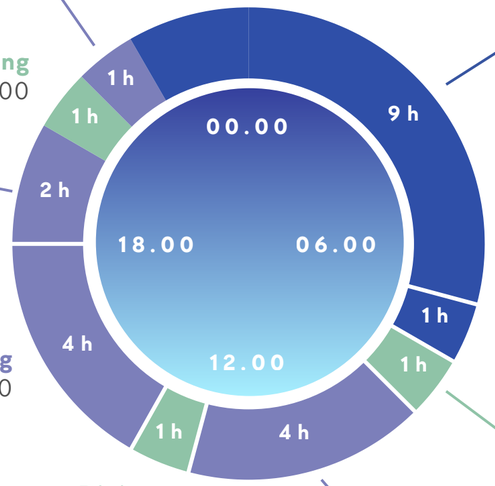
Relaxing
21.00 - 22.00

Dining
20.00 - 21.00

Relaxing / exercising
18.00 - 20.00



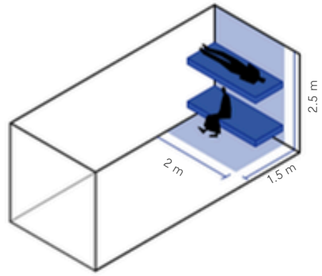
Demands **maximum clearance** of floor area.



Working
14.00 - 18.00

Dining
13.00 - 14.00

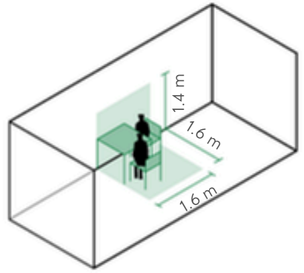
+ Storage space
of personal items, clothing, working equipment.
Fixed. **Compact**, to maximise space clearance
at least two modules



Sleeping
22.00 - 7.00

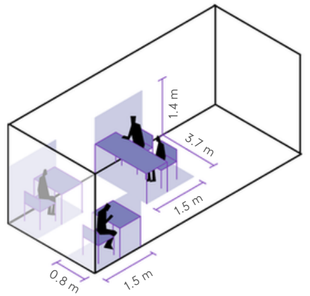
Highest duration. Lowest frequency, hence must **be folded away or reconfigured**. At **extremities** to minimise daytime circulation interference.

Hygiene
7.00 - 8.00



Dining
8.00 - 9.00

Highest frequency, hence must be **easily accessible.**



Working
9.00 - 13.00

Legend

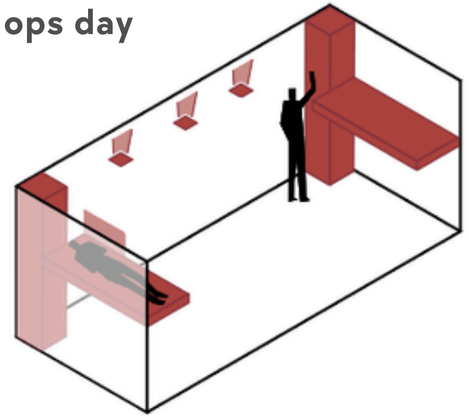
Individual peripheral zones

Collective central zones

Both demand two configurations, one for collective and one for private fruition

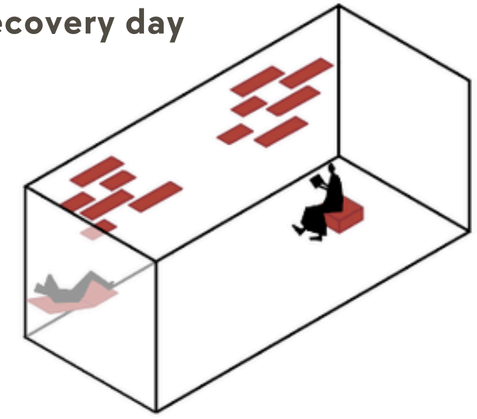
02 ACTIVITY MAPPING | SCENARIO ANALYSIS

1 - Standard ops day



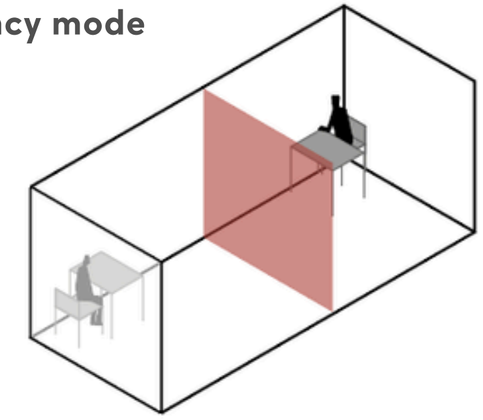
Separate beds with integrated personal storage and privacy separator. For optimized circulation with no functional overlap and light and acoustic shielding in sleeping zone.

2 - Active recovery day



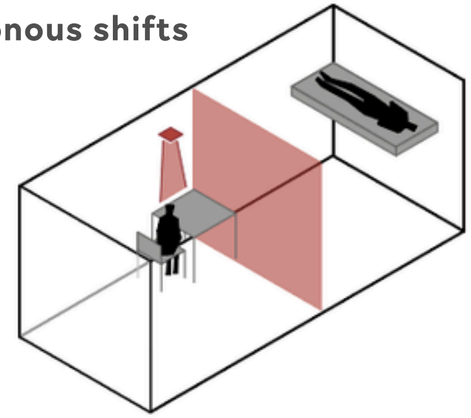
Adjustable modules for user-driven spatial reconfiguration to enable environmental personalization and reduce visual monotony.

3 - Emergency mode



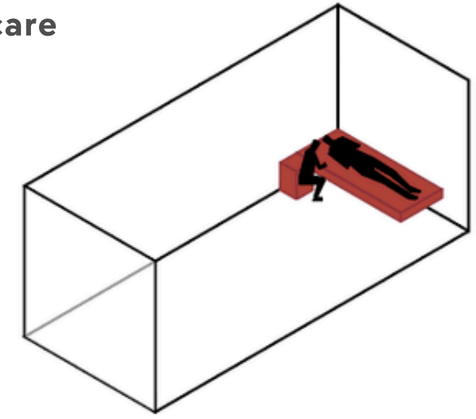
Foldable partition to subdivide container into two private rooms. For increased privacy and psychological benefits during prolonged isolation

4 - Asynchronous shifts



Foldable partition to subdivide container into two private rooms.. Indepentent light control between the two zones. For increase acoustic and light insulation.

5 - Patient care



Bed at ergonomic standing height and integrated bedside surface to enable assisted care.

03 LECTURE SUMMARY | VORONOI

What is Voronoi?

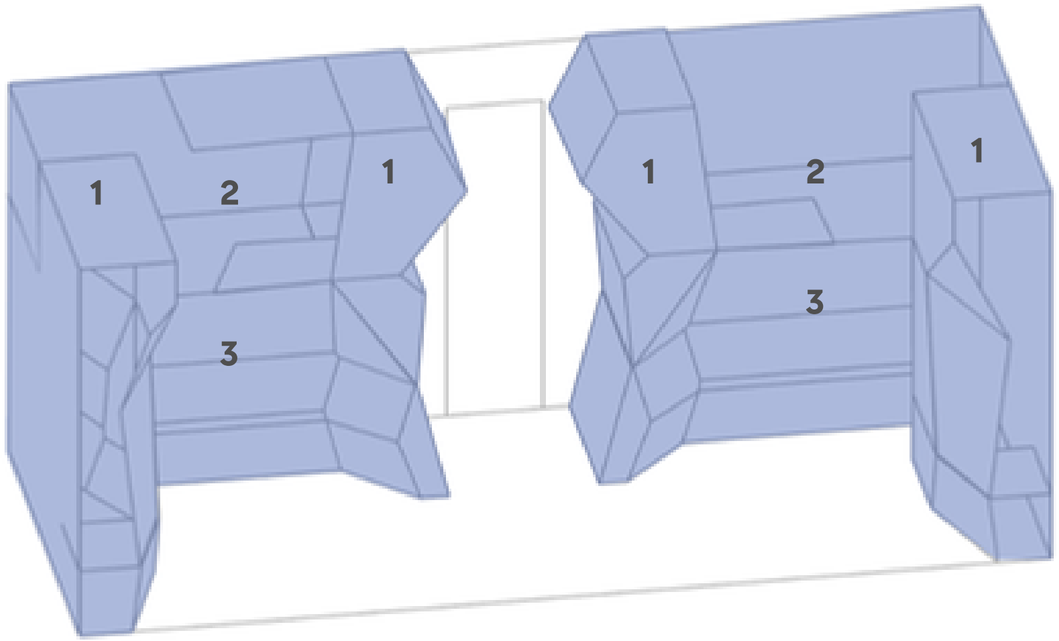
- Mathematical Partitioning: Dividing space into cells based on proximity to "seed points."
- Nature’s Blueprint
- Organic Efficiency: eliminating "dead corners"

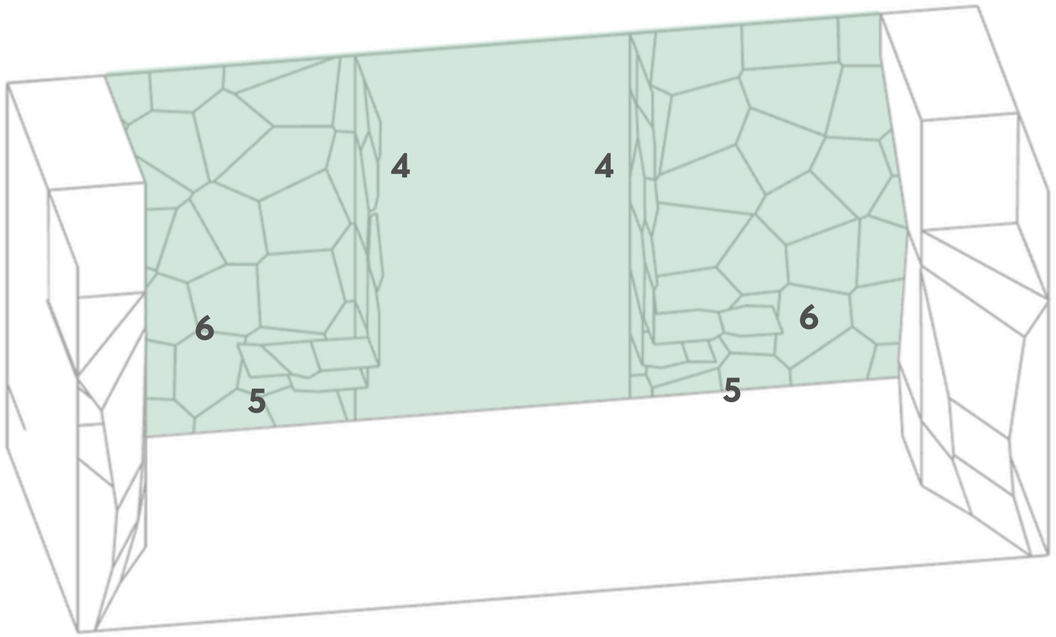
Application & Objective

- Optimal Spatial Efficiency
- Transforming "stiff" furniture into foldable furniture
- Breaking the Box: eliminates "tunnel vision"

04 ADAPTIVE FURNISHING | OVERVIEW

Distribution principles





Legend

Static core

More space-consuming and/or fixed furnitures are placed adjacent to the walls. For individual fruition

1. Storage 2. Bed 3. Workstation

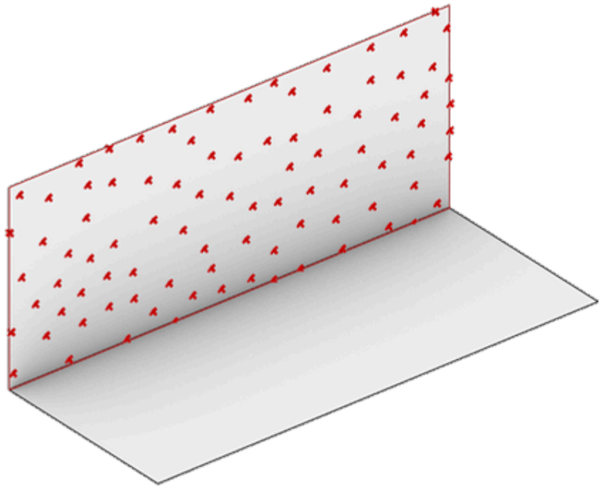
Kinetic skin

Furniture in the center of the container is easily reconfigurable and can be folded to a surface, for maximum clearance of the space. For both collective or individual fruition

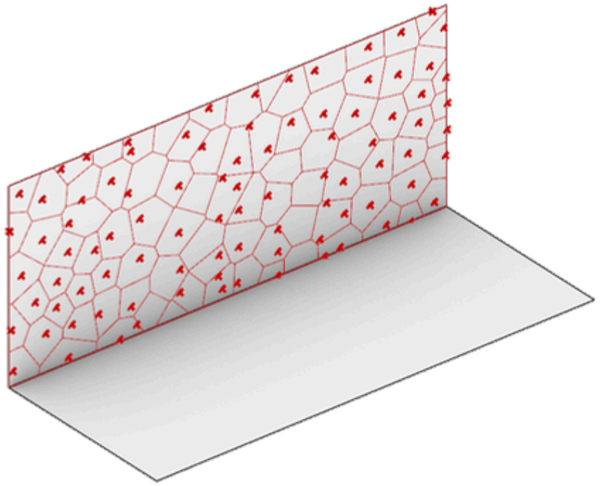
4. Multipurpose room divider 5. Chair/Lounge chair 6. Table

05 KINETIC SKIN | GENERATION PROCESS

Base Voronoi pattern

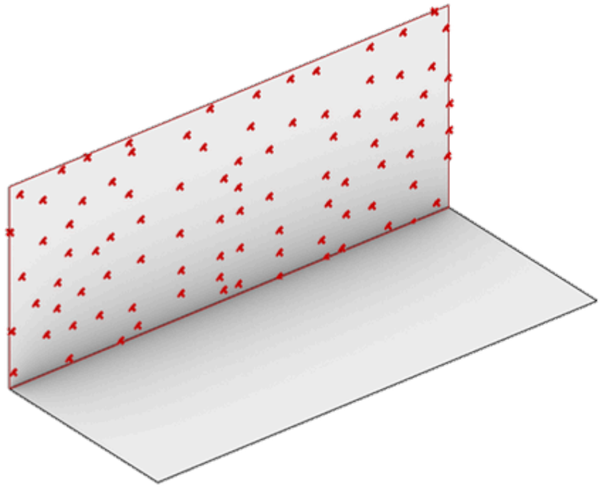


Voronoi points population on the wall plane

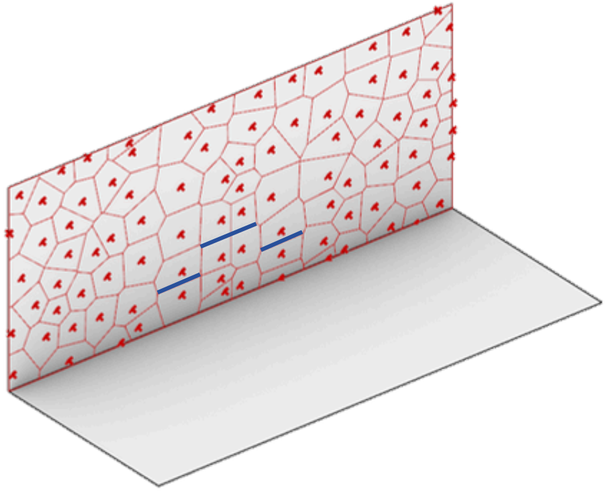


Checking how the generated cells look like

Re-arranged pattern

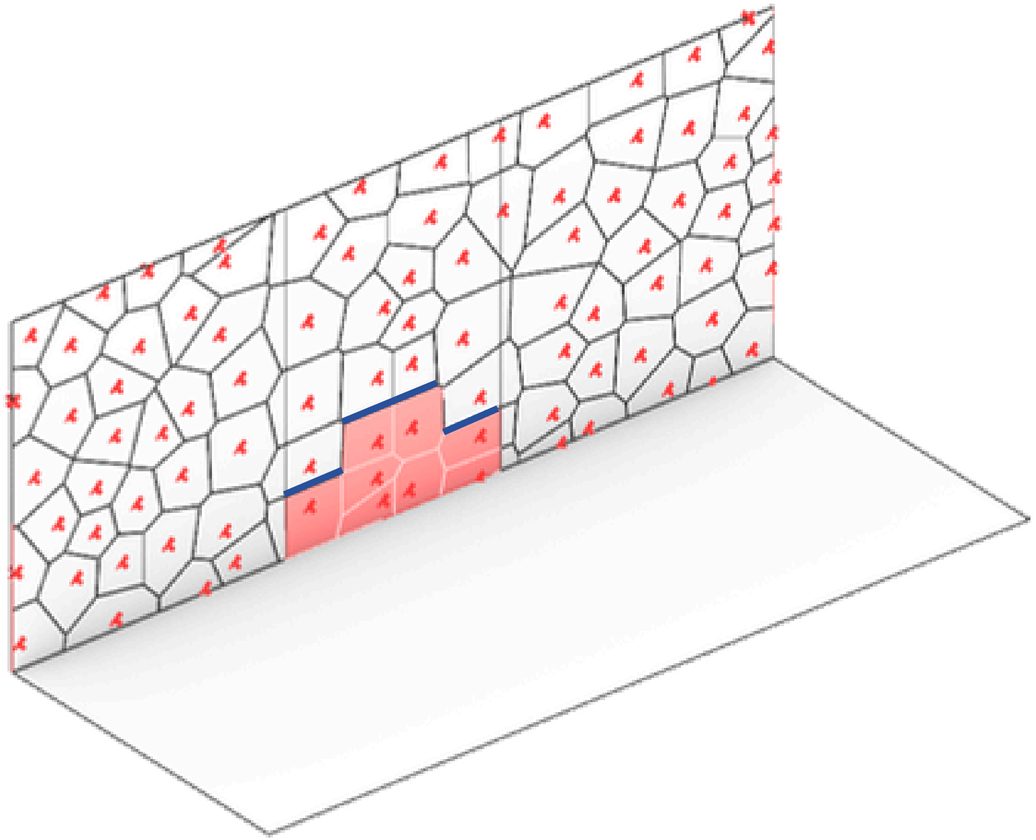


Manually re-arranging the Voronoi points to have horizontal demarcations for folds

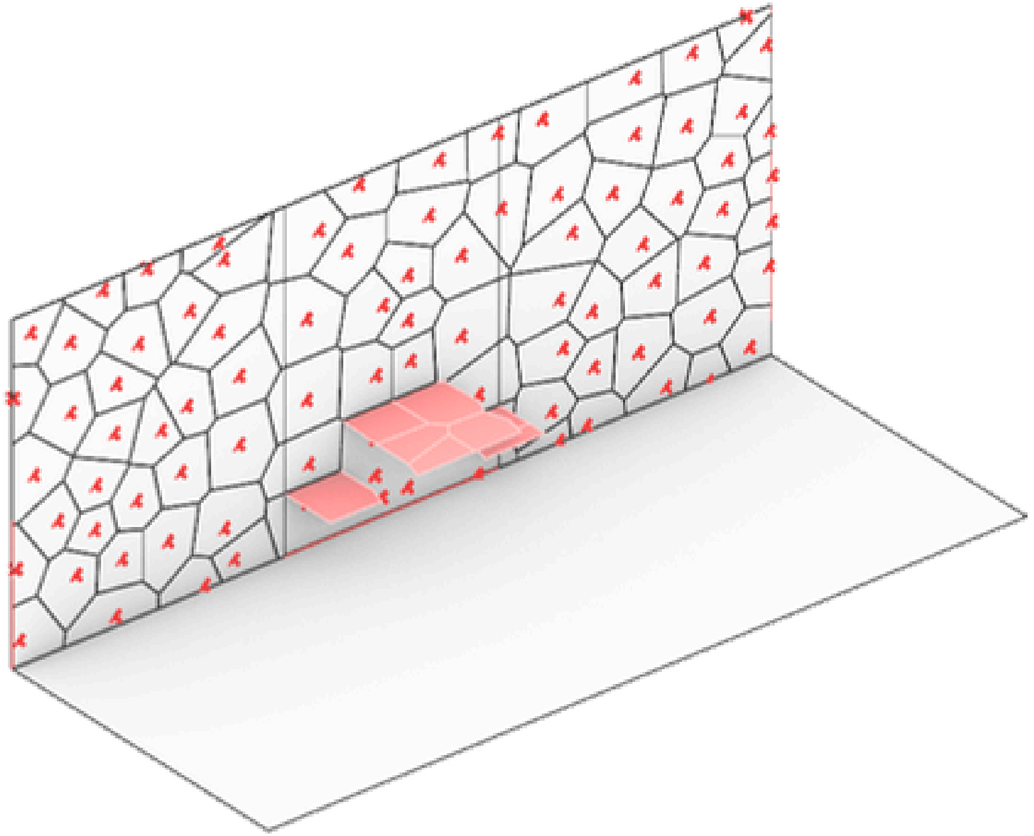


Organization of the newly generated cells

05 KINETIC SKIN | GENERATION PROCESS



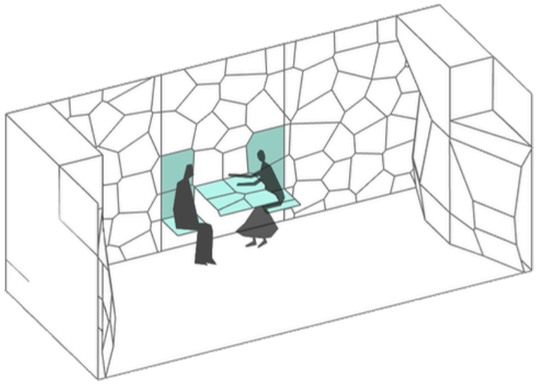
Selecting the cells for the seating and table



Unfolded seating and table

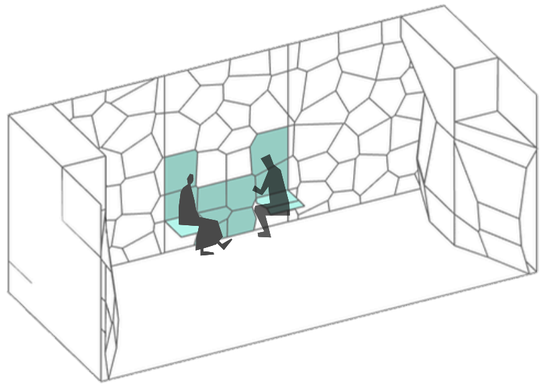
06 KINETIC SKIN | CONFIGURATIONS

Collective



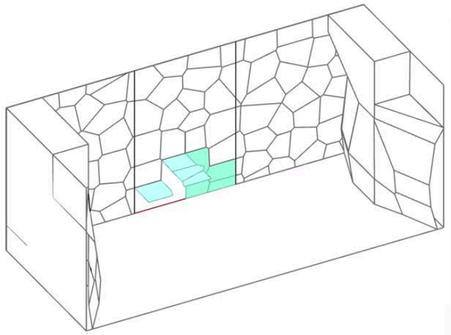
Dining table and chairs open (for dining)

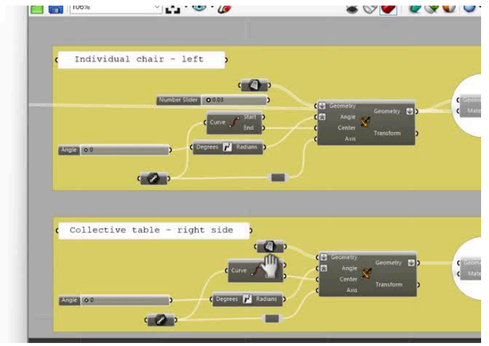
8.00h-9.00h, 13.00h-14.00h, 20.00h-21.00h

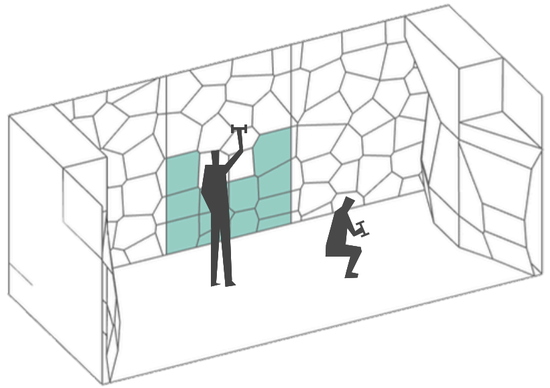


Just chairs open (for socialising)

8.00h-9.00h, 13.00h-14.00h, 14.00-18.00
20.00h-21.00h





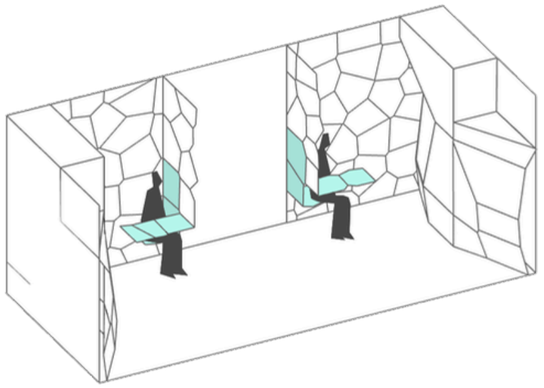


Everything closed (for collective excercising)

18.00h-20.00h

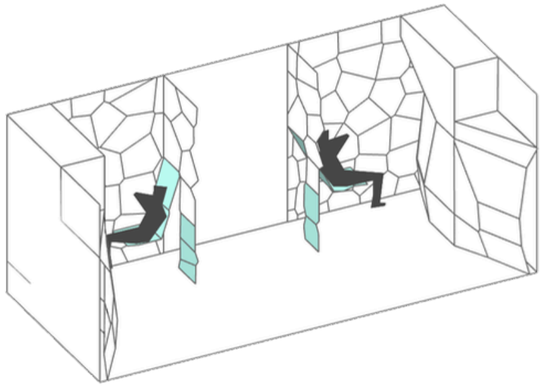
06 KINETIC SKIN | CONFIGURATIONS

Individual



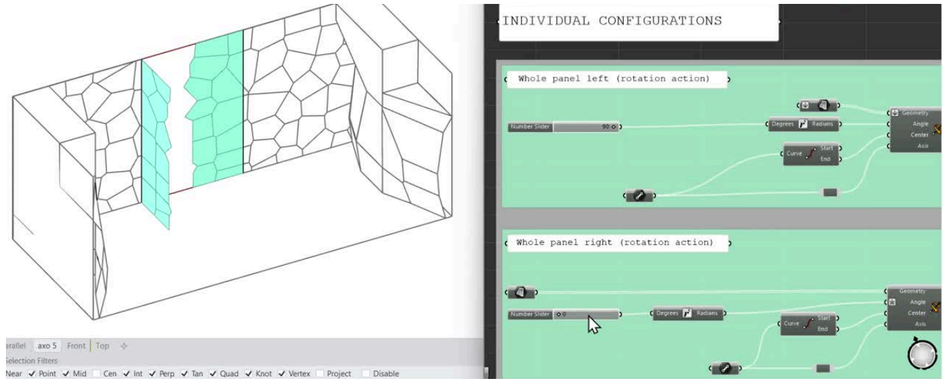
Individual table + chair open (for individual dining)

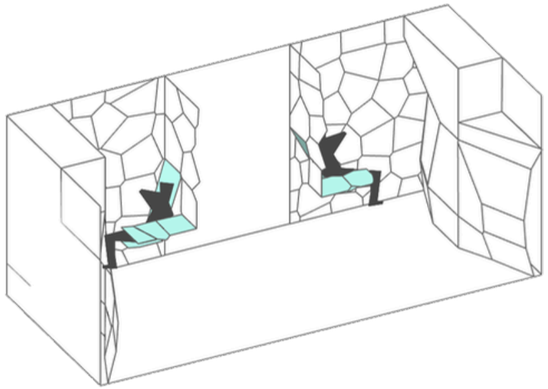
8.00h-9.00h, 13.00h-14.00h, 20.00h-21.00h



Lounge chairs open (for resting)

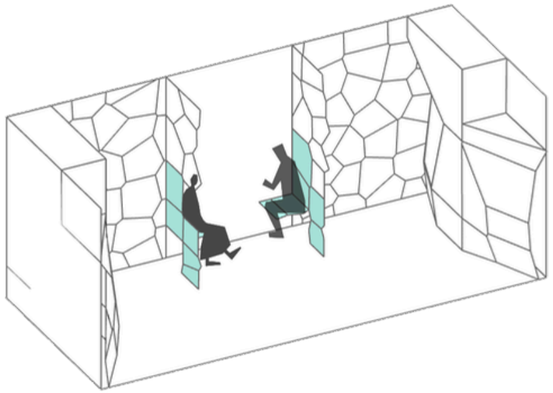
18.00h-20.00h, 21.00-22.00





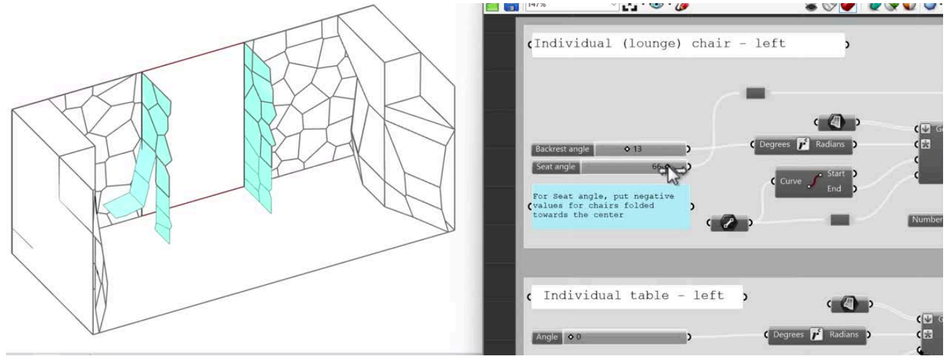
Lounge chair + individual table open (for resting with side table next to it)

18.00h-20.00h, 21.00h-22.00h



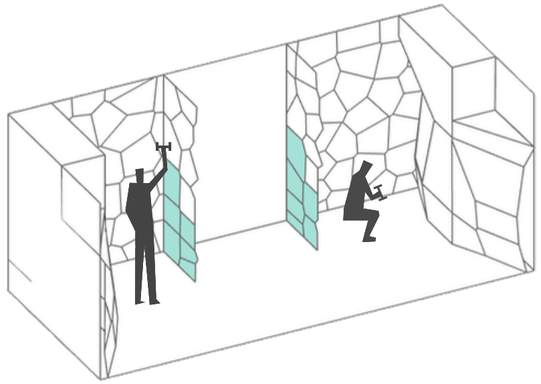
Chairs folded towards the center (for socialising while maintaining privacy inside the room)

9.00h-13.00h

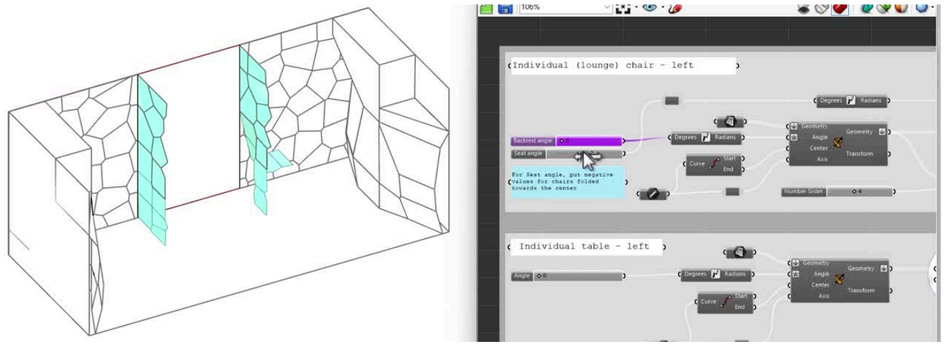


06 KINETIC SKIN | CONFIGURATIONS

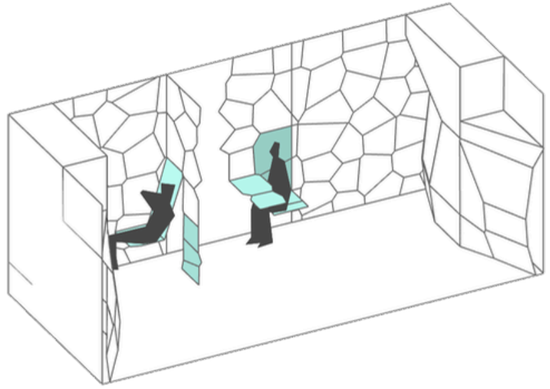
Individual



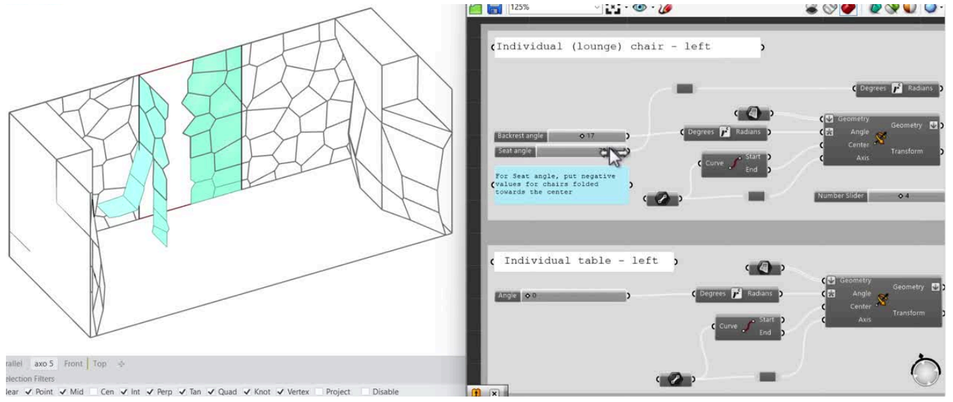
Just wall (for individual excercising) 18.00h-20.00h



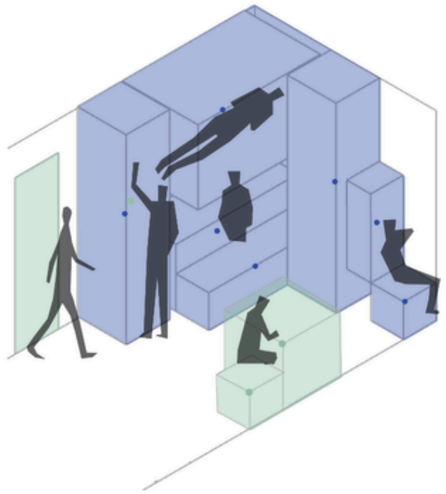
Hybrid

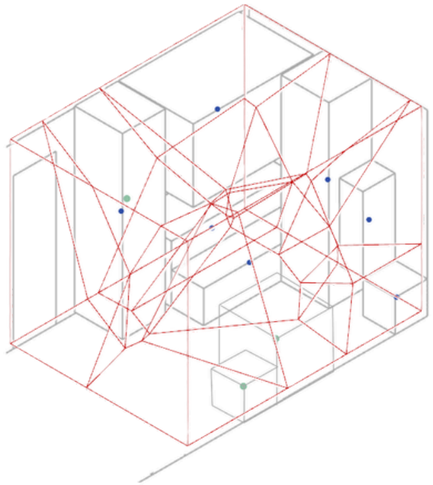


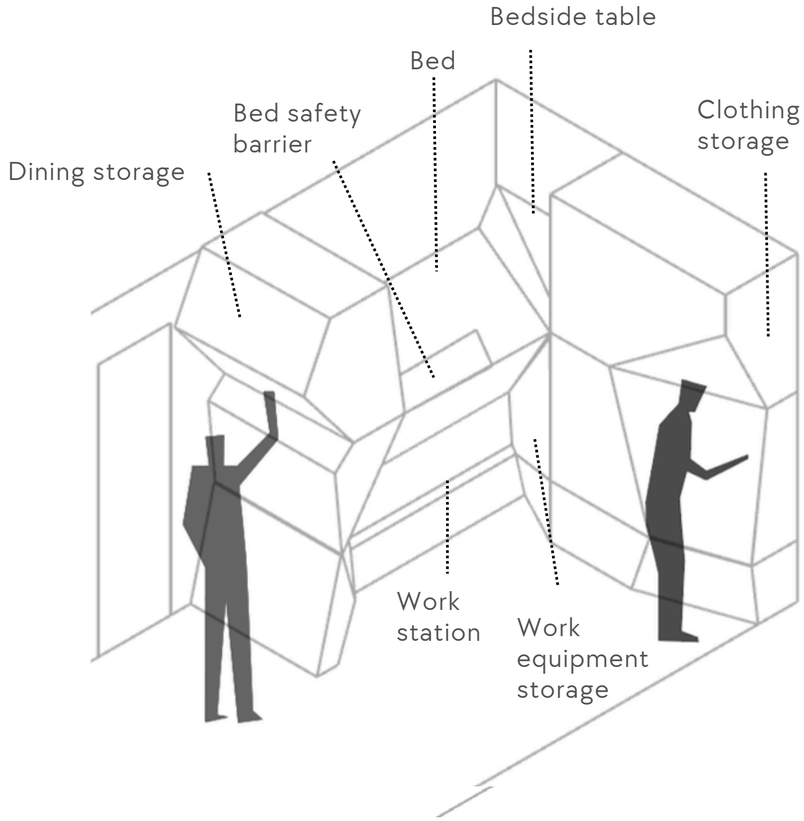
Lounge chair in individual configuration, dining
in collective one 18.00h-20.00h



07 STATIC CORE | GENERATION PROCESS







Process

1. **Optimisation of activities distribution in space**

minimal dimensions obtained from activity mapping

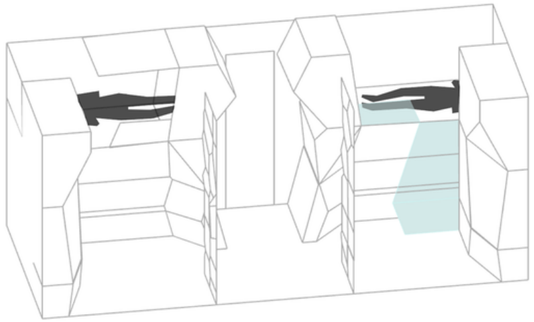
2. **Centroids as seeds points**

minimal dimensions obtained from activity mapping

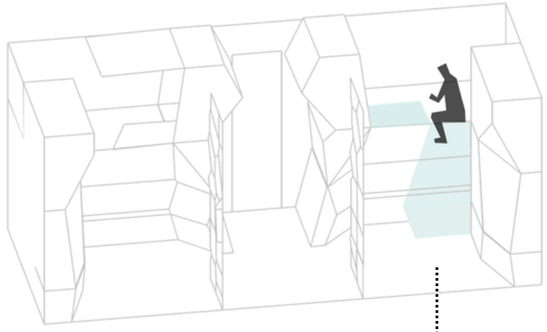
Optimised ergonomic design

08 ADAPTIVE FURNISHING | 24H MAPPING

6.00-7.00: Waking up & Hygine - User 1

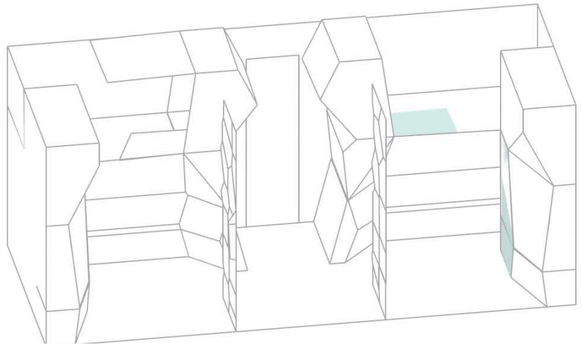


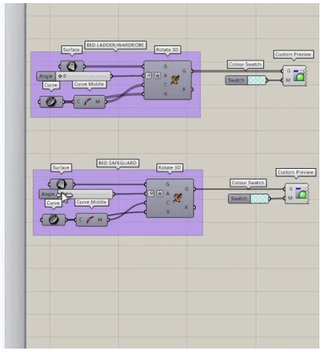
Waking up

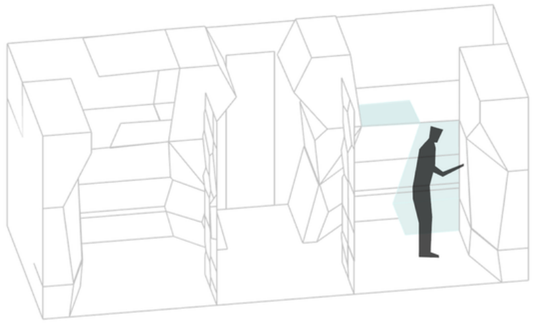


Getting off the bed

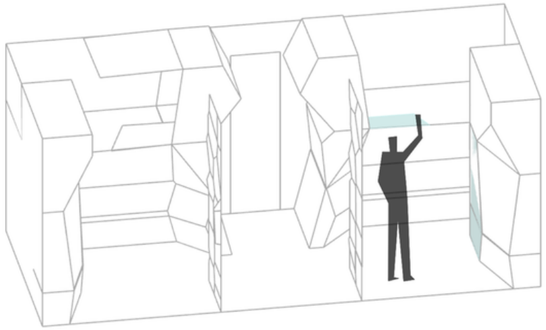
Bed ladder integrated in clothing storage surface







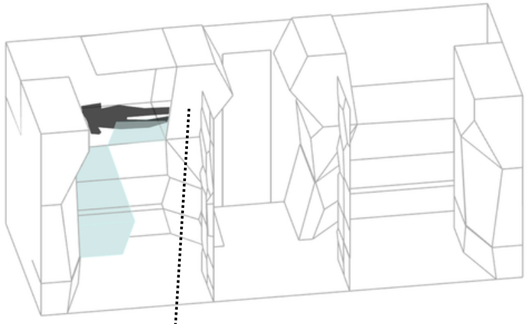
Getting clothes from wardrobe



Closing wardrobe and bed safety barrier

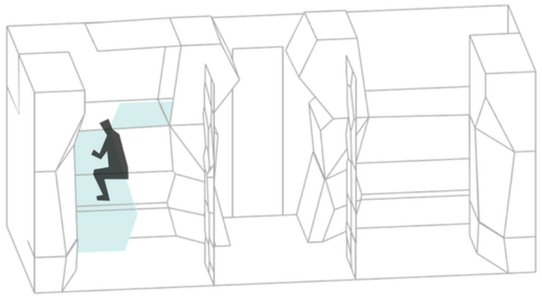
08 ADAPTIVE FURNISHING | 24H MAPPING

7.00-8.00: Waking up & Hygine - User 2

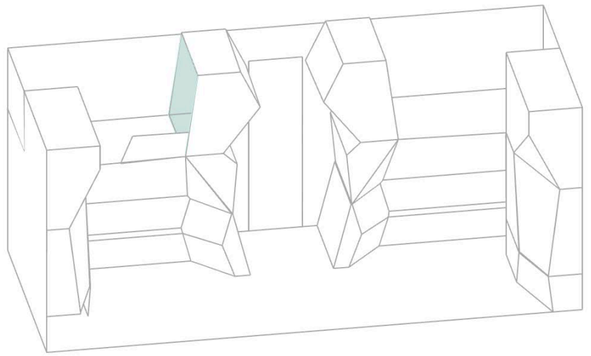


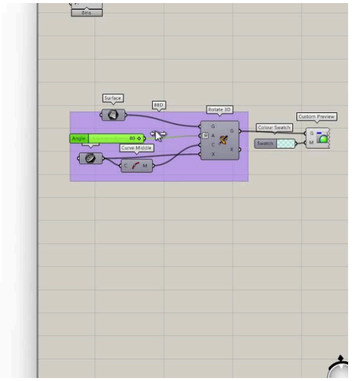
Waking up

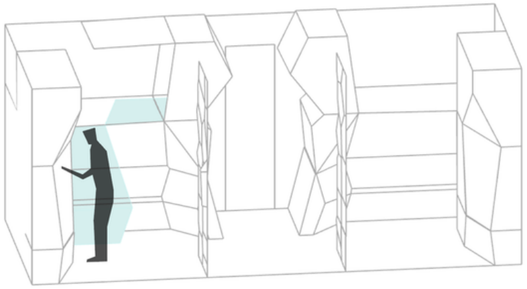
Extended bed
(alternatively serving as
additional storage)



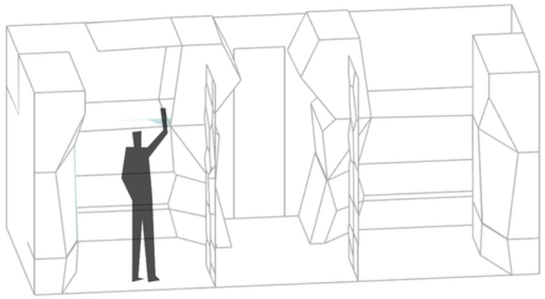
Getting off the bed







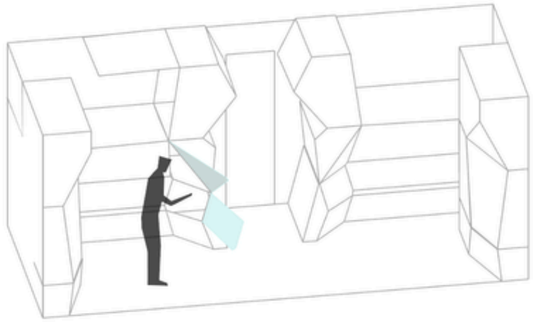
Getting clothes from wardrobe



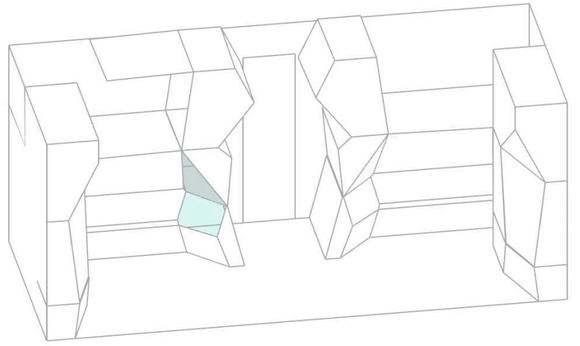
Closing wardrobe and bed safety barrier

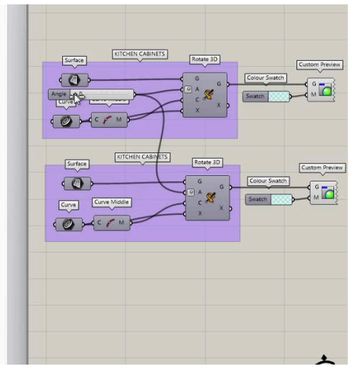
08 ADAPTIVE FURNISHING | 24H MAPPING

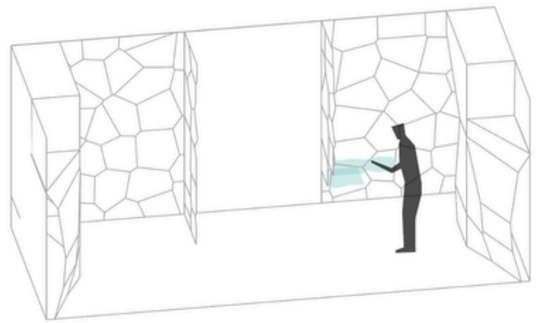
8.00-9.00: Individual Dining - User 2



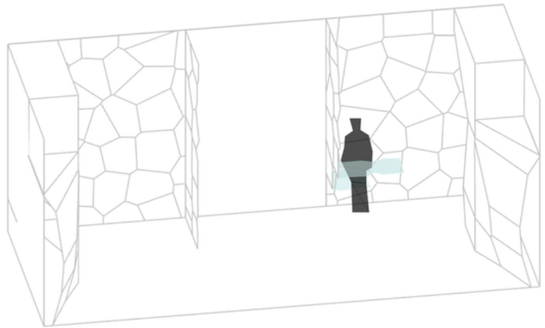
Getting food/dishes from kitchen storage



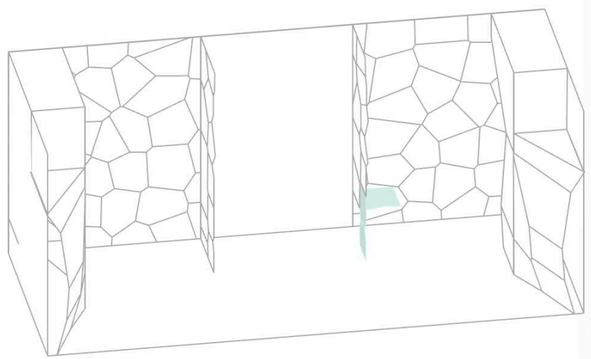


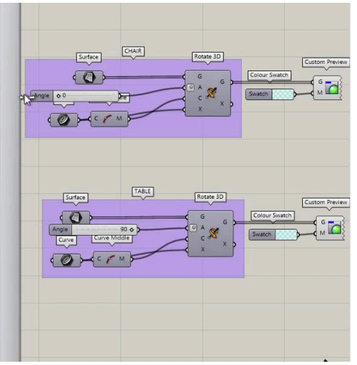


Folding out dining chair and table



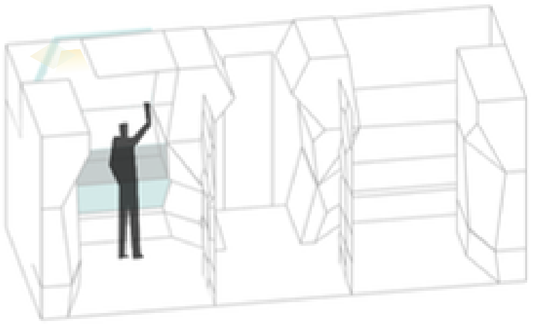
Having breakfast





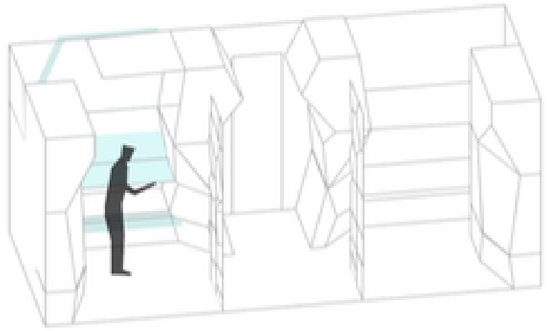
08 ADAPTIVE FURNISHING | 24H MAPPING

9.00-13.00: Individual Working - User 2

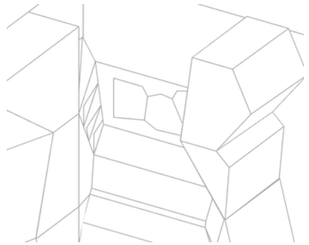


Folding away bed

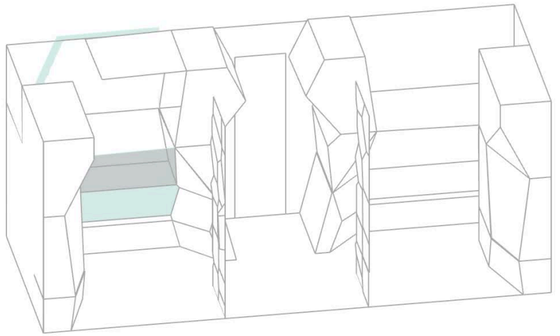
Allows fruition of larger space in heigth, natural light and view of the sky from skylight above bed

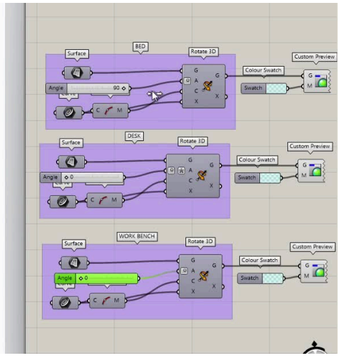


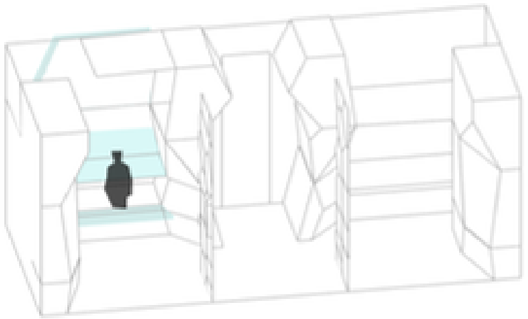
Folding out desk and work bench



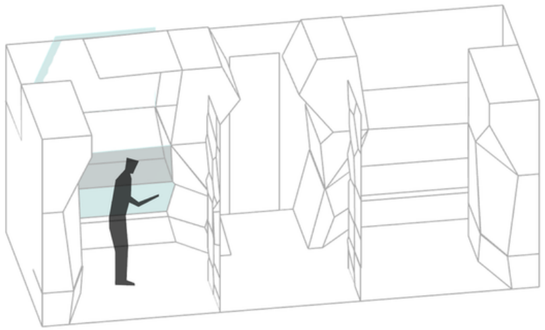
allows fruition of window and storage







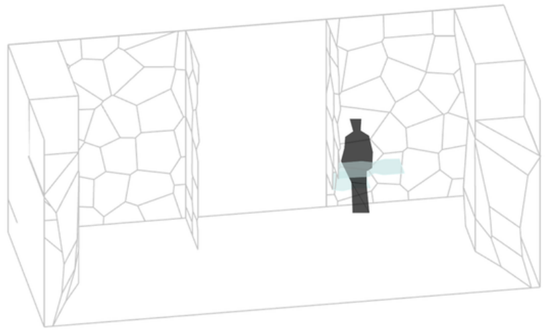
Working



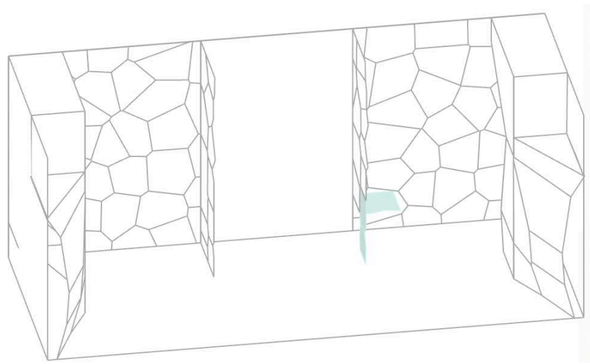
Folding in desk and work bench

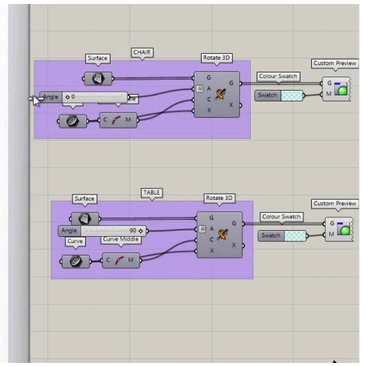
08 ADAPTIVE FURNISHING | 24H MAPPING

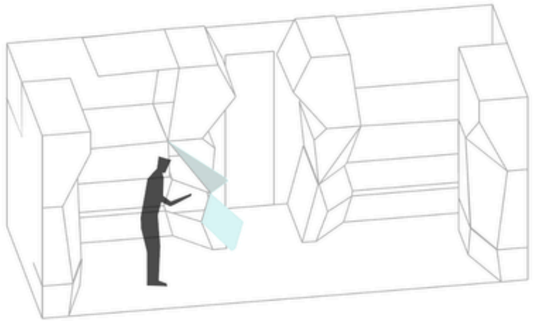
13.00-14.00: Individual Dining - User 2



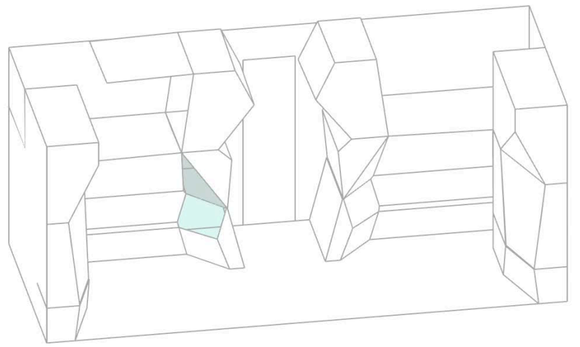
Having lunch

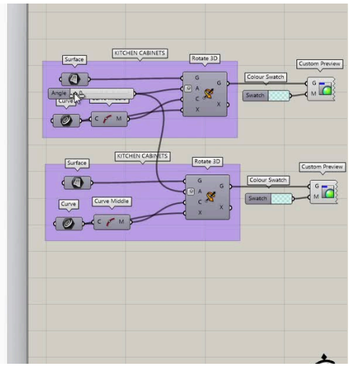






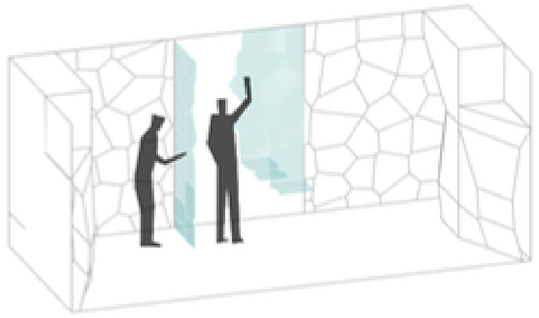
Putting food/dishes back in kitchen storage



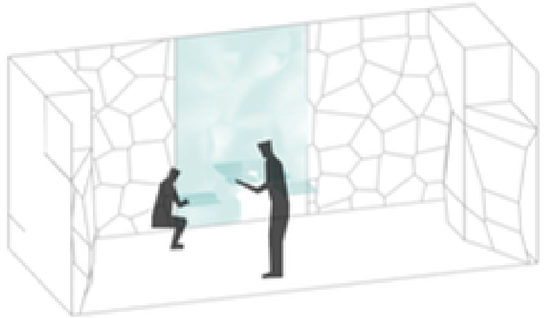


08 ADAPTIVE FURNISHING | 24H MAPPING

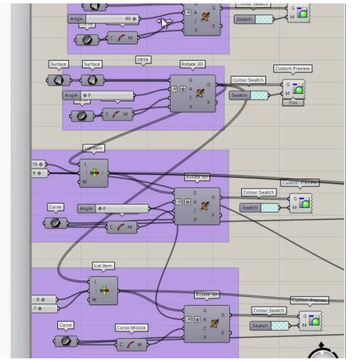
14.00-18.00: Collective Working

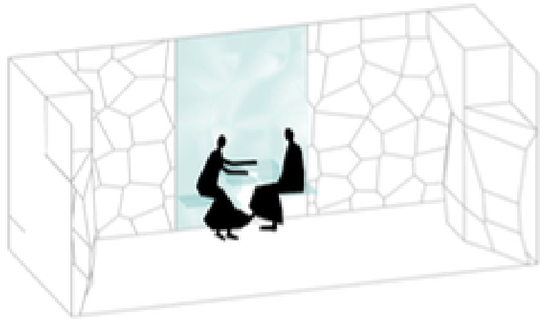


Reconfiguring walls



Folding out table and chair

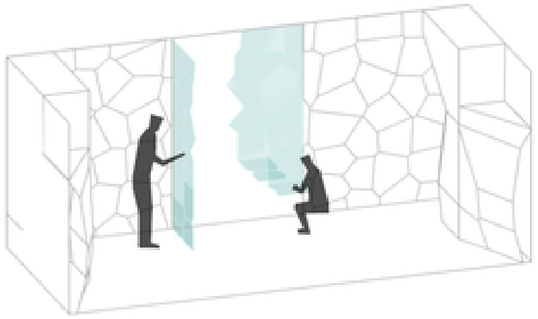




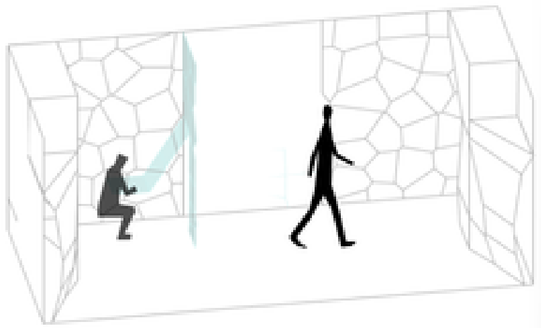
Working

08 ADAPTIVE FURNISHING | 24H MAPPING

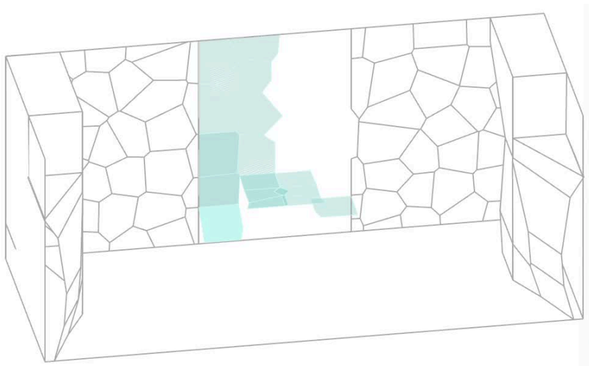
18.00-20.00: Relaxing/Exercising

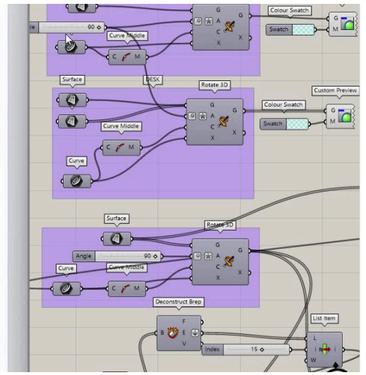


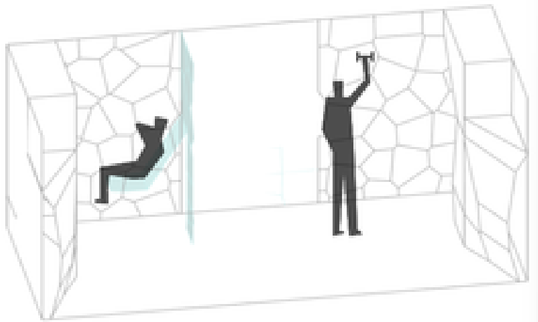
Reconfiguring walls



Folding out lounge chair



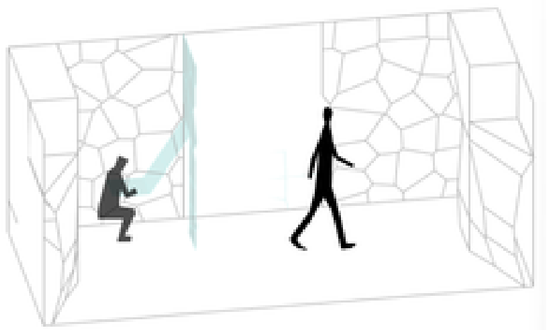




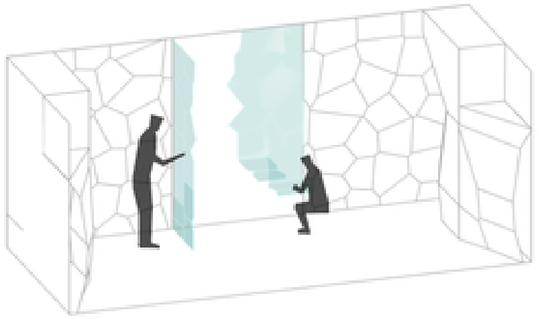
Relaxing/exercising

08 ADAPTIVE FURNISHING | 24H MAPPING

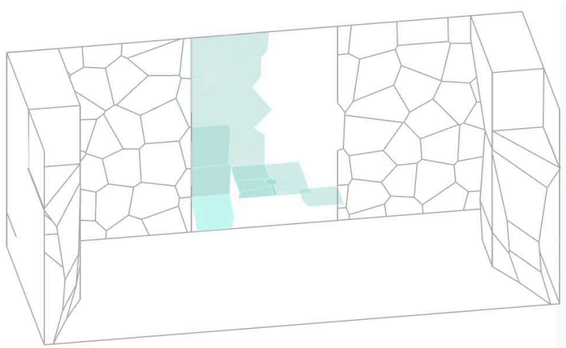
20.00-21.00: Collective dining

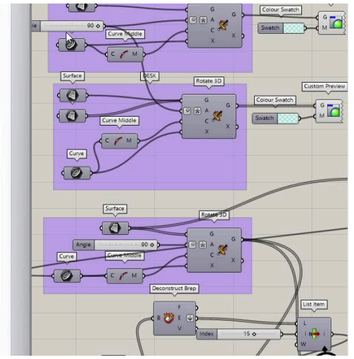


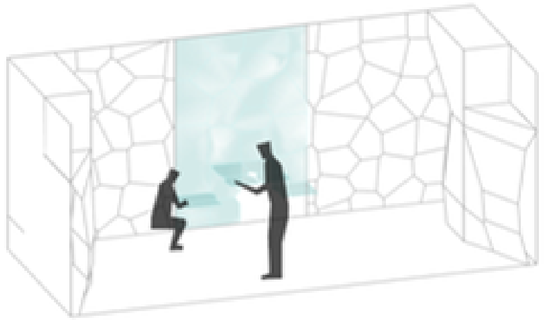
Folding away lounge chair



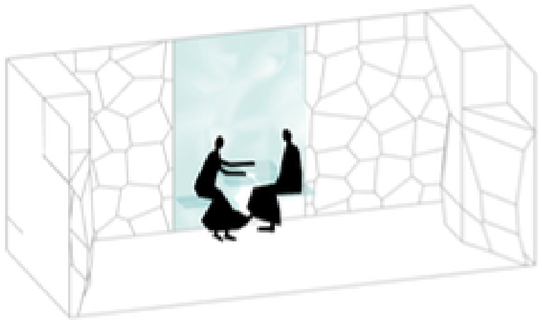
Reconfiguring walls







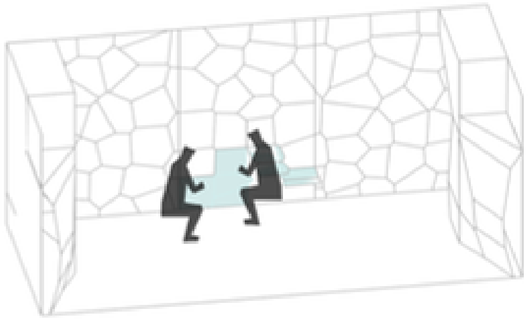
Folding out table and chairs



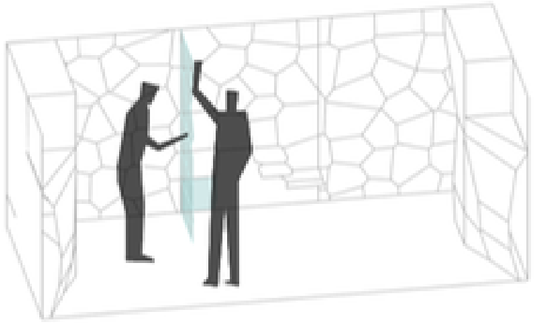
Dining

08 ADAPTIVE FURNISHING | 24H MAPPING

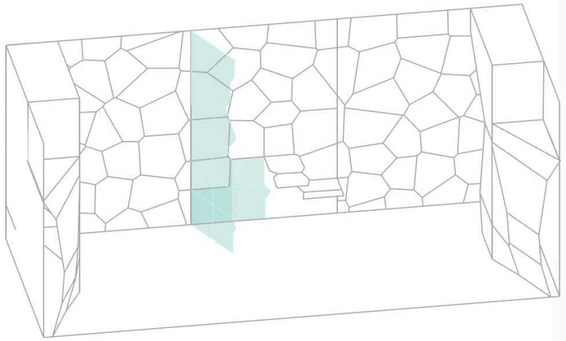
21.00-22.00: Relaxing

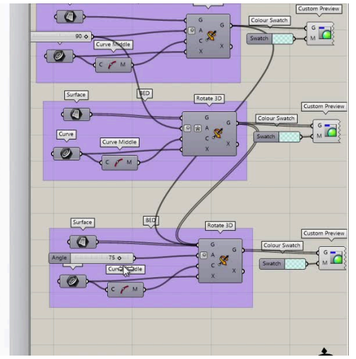


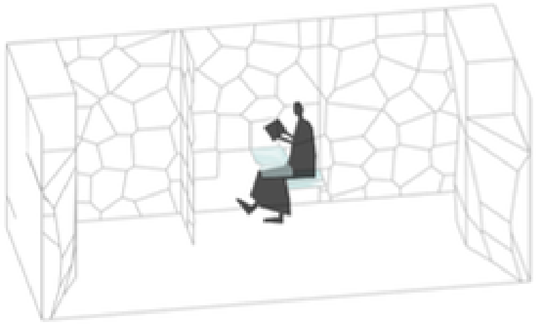
Folding in chair and table



Reconfiguring wall



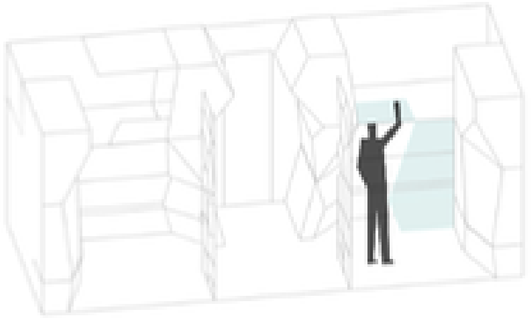




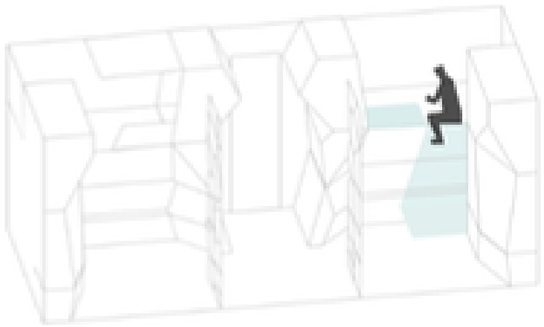
Relaxing

08 ADAPTIVE FURNISHING | 24H MAPPING

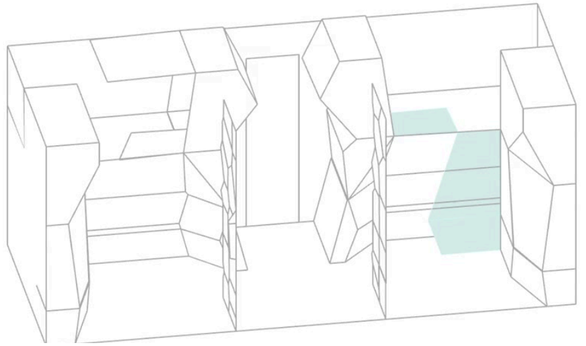
21.00-22.00: Relaxing & Sleeping - User 1

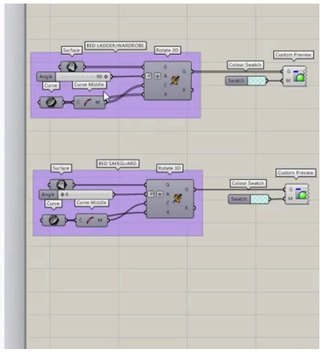


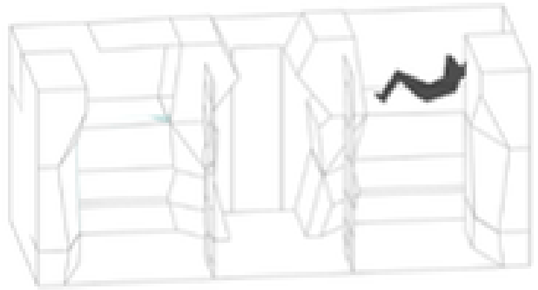
Folding out ladder and bed safety barrier



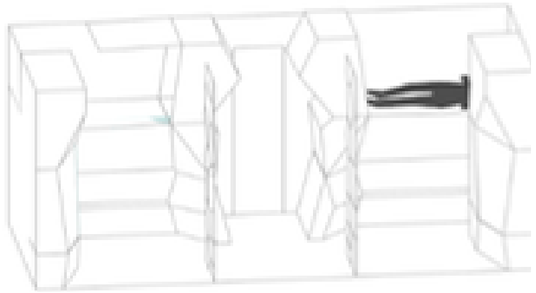
Climbing up the bed







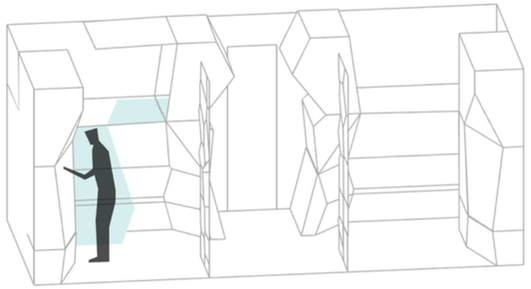
In bed activities



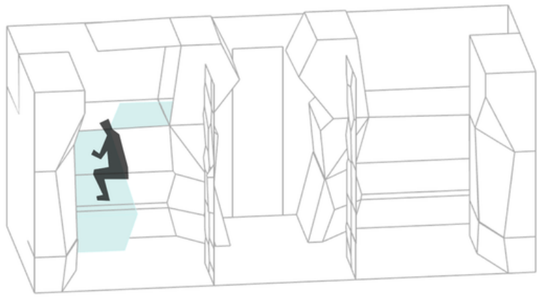
Sleeping

08 ADAPTIVE FURNISHING | 24H MAPPING

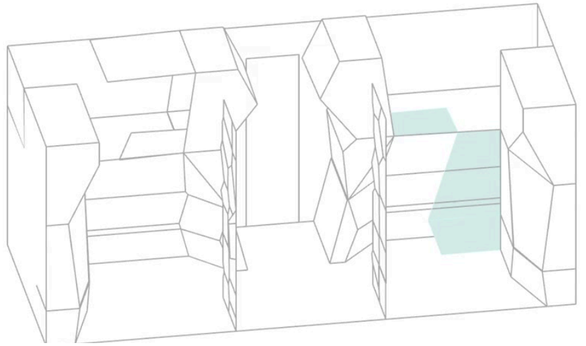
22.00-23.00: Sleeping - User 2

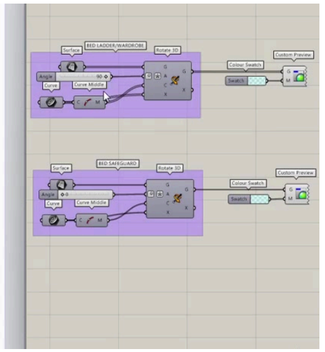


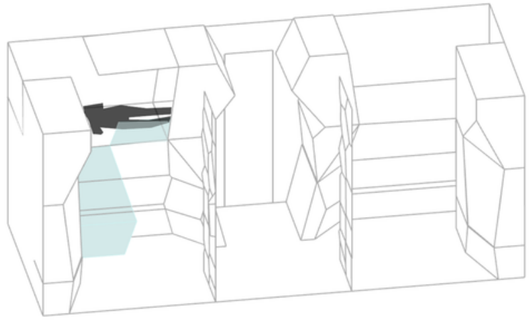
Foldinf out ladder and bed safety barrier



Climbing up the bed



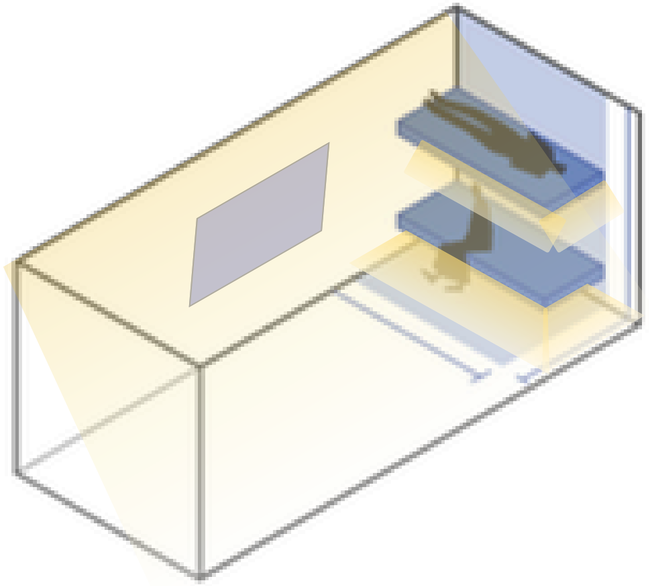




Sleeping

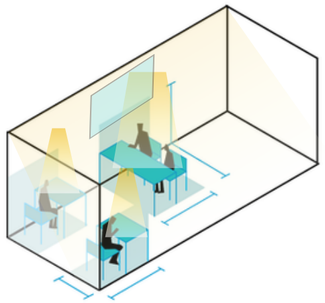
09 LIGHTING | NEEDS

Base lighting



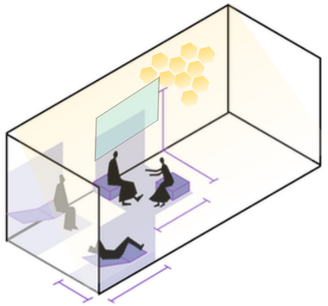
Primary

Task lighting



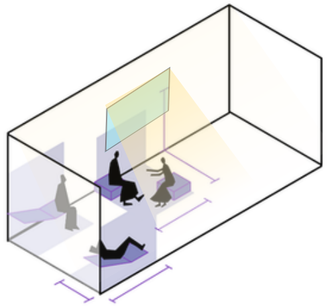
Secondary

Ambient lighting



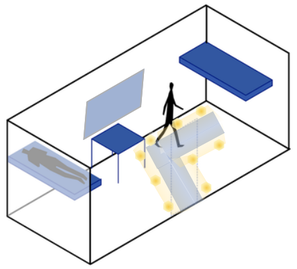
Secondary

Natural light



Secondary

Navigating lighting



Tertiary

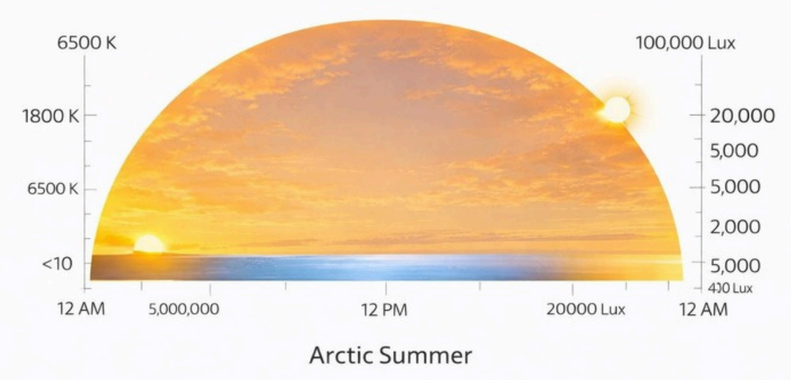
LIGHTING | ARCTIC AND CIRCADIAN

- **Arctic winter**: the sun never rises above the horizon-> no direct sunlight, dim light 1-50lux and very cool blue twilight
- **Arctic summer**: the sun never sets, moves circular in the sky --> low angle warm light, 5-20,000 and 20.000-100.000 lux

- **Circadian cycle**: Bright daytime light, dark nights and regular 24h cycles

Problem:

Arctic conditions provide either
- **Too much light → Summer**
- **Too little light → Winter**



Arctic Summer

Arctic Winter

Solution:

Permanent Circadian sleep/wake light cyle
- artificially managed

Is there any way to use the Arctic light?

10 LIGHTING | ARCTIC AND CIRCADIAN

Windows are **not a reliable primary light source** in the Arctic environment
But provide **essential phycophysiological benefits**

Window eye level

For **orientation**:

- seeing the outside → improves wellbeing through visual connection
- make the space 'feel' wider & less isolated
- **helps to stay connected to outside world**

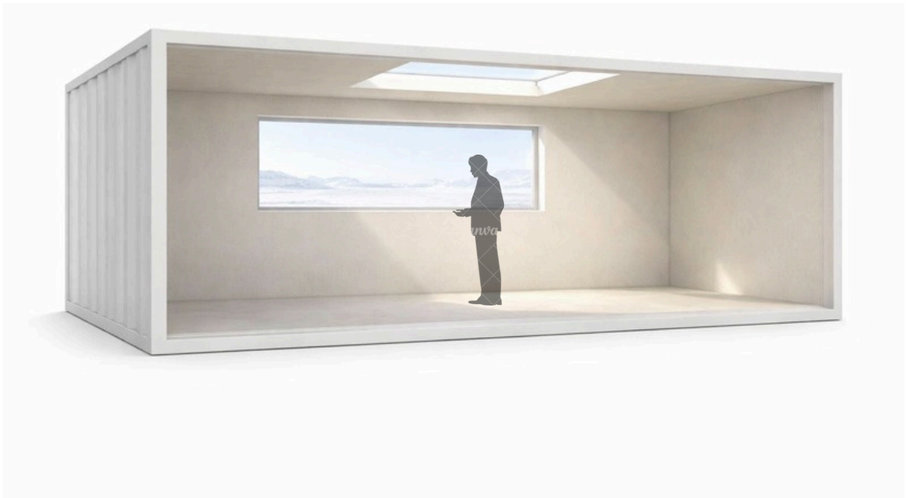
Skylight window

For **light**:

- gives a stronger 'feeling' of daylight
- help space feel less enclosed
- **works well together with artificial circadian lighting**

Arctic summer

Arctic winter



LIGHTING | ARCTIC AND CIRCADIAN

Windows can support the circadian light cycle inside the container
but **must be controlled to support the system**

Arctic summer

There is <u>too much light</u> from the window

- Solar-control glass, filters brightness
- Diffusion, softens glare
- Shading, blocks excess light (lux-sensors)
- Artificial night, shading blocks all natural light
- **Artificial lighting dims to maintain circadian schedule inside with AI (lux- & CCT-sensors)**

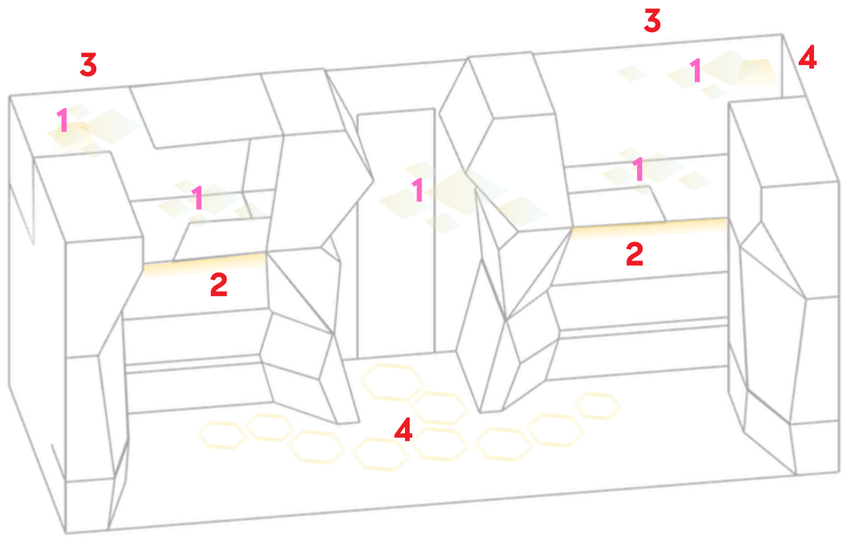
Arctic winter

There is <u>too little light</u> from the window

- Circadian daylight cycle as primary light provider
- is about perception an information not light
- **Artificial lighting adjusts color to maintain circadian schedule inside with AI (CCT-sensors)**

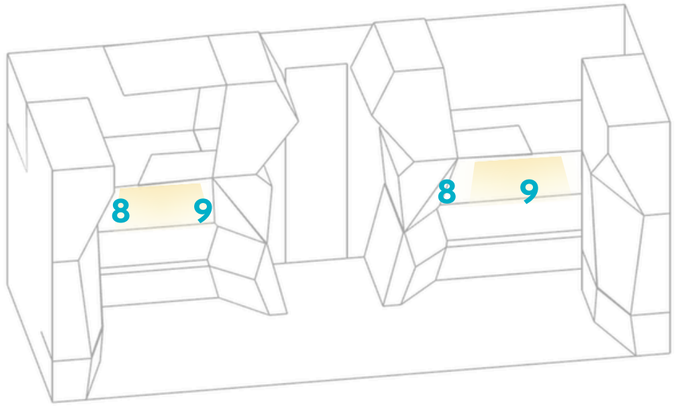
The AI system **dynamically adjusts intensity and CCT** in relation to outside to maintain the “controlled artificial day” despite changing external lighting conditions.

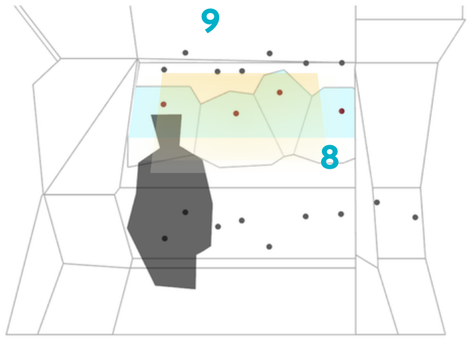
11 LIGHTING OVERVIEW

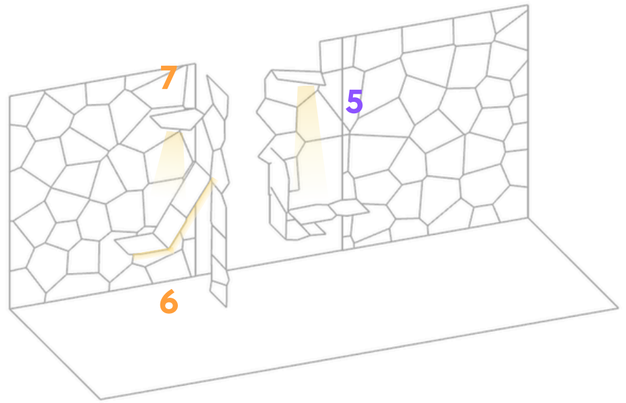


	What	Location	Type	Control settings	Control system on/off	Control system lux/CCT	AI feature
1	**Sleep/ wake cycle** day activities	voronoi cells on the ceiling, cells on wall	diffused	Collective	Automatic schedule & biometric sensors	Smartwatch/External sensors	
2	**Sleeping** In bed activities	Under the frame of the bed	diffused	Individual	Computer Vision/smartwatch	Smartwatch (alarm)	Turning off after no movement for x hours
3	**Sleeping** In bed activities	To the side of the head	direct	Individual	Smartwatch	Smartwatch	
4	**Sleeping/ Emergency** To navigate in darkness	on the floor/lower wall	glow	Collective	Computer vision	Computer vision	Responding in emergency situation

11 LIGHTING OVERVIEW







	What	Location	Type	Control settings	Control system on/off	Control system lux/CCT	AI feature
5	**Dining**	Above table	direct	Collective	Computer vision	Computer vision & smartwatch	
6	**Relaxing**	On wall cells/ under surfaces	diffused	Collective/individual	Computer vision	Smartwatch (ID)	bpm & blink rate
7	**Relaxing**	Above lounge chair	direct	Individual	Computer vision/Manual switch	Smartwatch (ID)	bpm & blink rate
8	**Working**	Above desk	direct	Individual	Computer vision	Smartwatch (Stress)	
9	**Working**	Integrated in widow	diffused	Individual	Computer vision	Smartwatch (Stress)/External sensors	

LIGHTING | OPTIMAL LUX AND CCT

Primary

Activity / Moment	Purpose of Circadian Lighting	Illuminance (Lux)	CCT (Kelvin)
Wake-up / Morning	Gentle activation, start of daily rhythm	100–300 lux	2700–4000 K
Working	Increase alertness and maintain daytime rhythm	500–800 lux	5000–6500 K
Lounging	Maintain daily rhythm during lower-activity moments	100–200 lux	2700–3500 K
Dining	Maintain rhythm during shared meals	200–350 lux	3000–4000 K
In-bed activities	Prepare body for rest while keeping temporal cue	0–50 lux	1800–2700 K
Sleeping	Support sleep cycle, minimal biological stimulation	0–30 lux	1800–2200 K

heart_rate_bpm

Physical state	Range	Notes	Lighting changes
Calm/relaxed	60-80 bpm	Resting heart rate	Nothing
Stressed	85-110 bpm	Higher than normal	reduce intensity, warmer light (+/- 3000 K)
Tired	50-65 bpm		If person needs to stay awake -> cooler color temperature (5000–6500 K) and 500–1000 lux

pupil_mm

Physical state	Range	Notes	Lighting changes
Calm/relaxed	2-4 mm ('normal' lighting)	Pupil is smaller than stress state	Nothing
Stressed	4-6 mm		reduce intensity, warmer light (+/- 3000 K)
Tired	2-3 mm	Smaller but unstable	If person needs to stay awake -> cooler color temperature (5000–6500 K) and 500–1000 lux

blink_rate_per_min

Physical state	Range	Notes	Lighting changes
Calm/relaxed	10-20 blinks/min	Natural blinking	Nothing
Stressed	20-35 blinks/min		reduce intensity, warmer light (+/- 3000 K)
Tired	20-40 blinks/min	Longer blinks, eyelid closure increases	If person needs to stay awake -> cooler color temperature (5000–6500 K) and 500–1000 lux

Secondary

Activity / Moment	Lighting Layer	Purpose	Illuminance (Lux)	CCT (Kelvin)
Working	Task lighting	Focus, detailed work	750–1000 lux	5000–6500 K
Lounging	Ambient lighting	Relaxed atmosphere	150–250 lux	2500–3000 K
Lounging / Reading	Task lighting	Reading support	150–300 lux	2700–3500 K
Dining	Ambient lighting	Warm social atmosphere	150–300 lux	2700–3500 K
In-bed activities	Ambient lighting	Calm background light	5–50 lux	2200–2700 K
In-bed activities	Task lighting	Reading / specific in-bed activity	150–300 lux	2700–3500 K
Night movement	Navigation lighting	Safe movement without disturbance	1–10 lux	1800–2200 K

LIGHTING AND AI |CONTROL SYSTEMS

Strategy
Minimise n of different control systems, detection errors and maintenance requirements

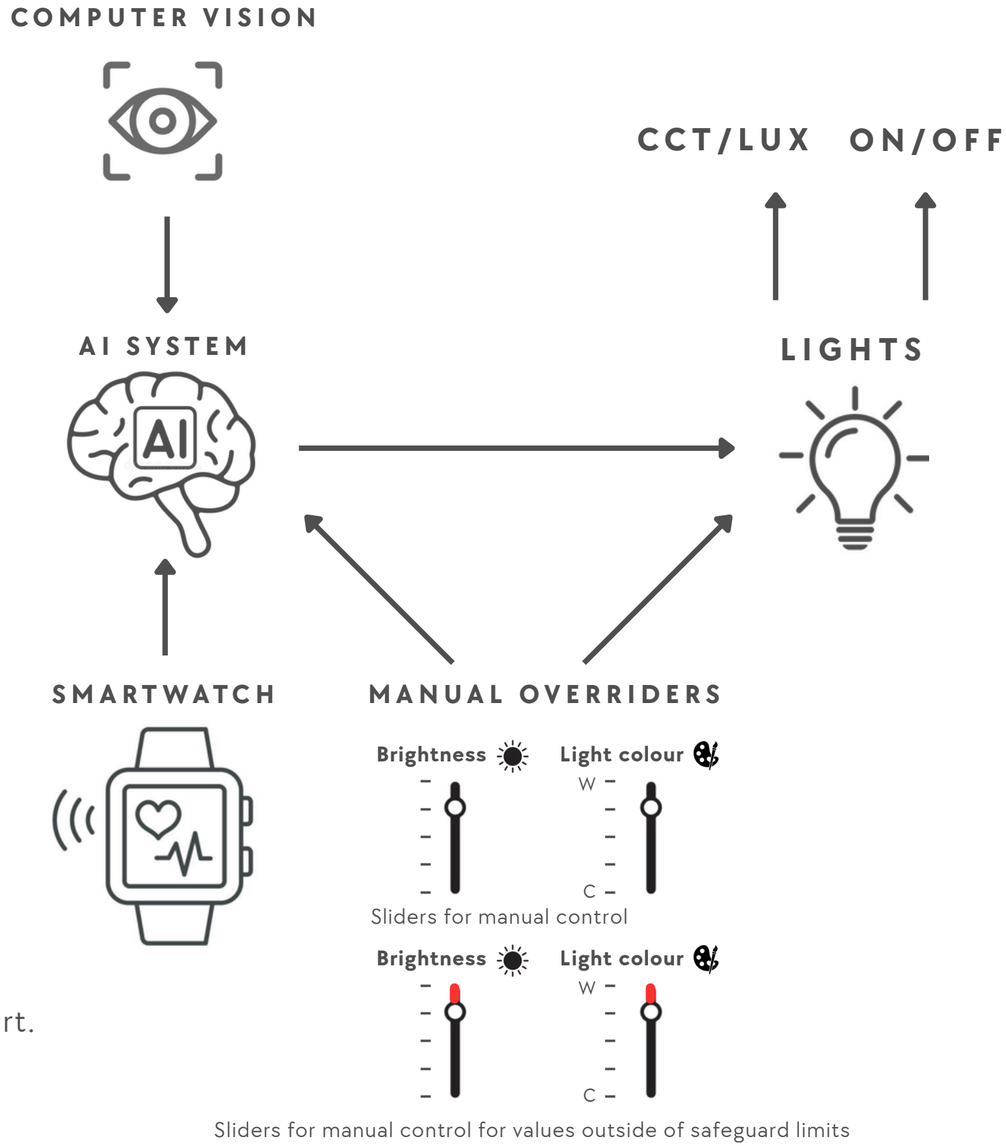
3 systems
- **Computer Vision (CV)** → Acts as the 'eyes'.
- **Smartwatch** → Provides the 'biological data'.
- **Manual Overrides** → Users can always take control via manual sliders

Hierarchy:
individual preferences and adaptation
environmental context

to do that: questionnaire and safeguard limits

Health Safeguards
- Red Warning: Shown when manual settings are outside healthy ranges.
- Corrective Fade: A gradual 30-minute transition back to healthy light levels.

Dual Control Logic
We distinguish between Trigger Control (turning lights on/off) and Atmospheric Control (adjusting CCT and Lux).



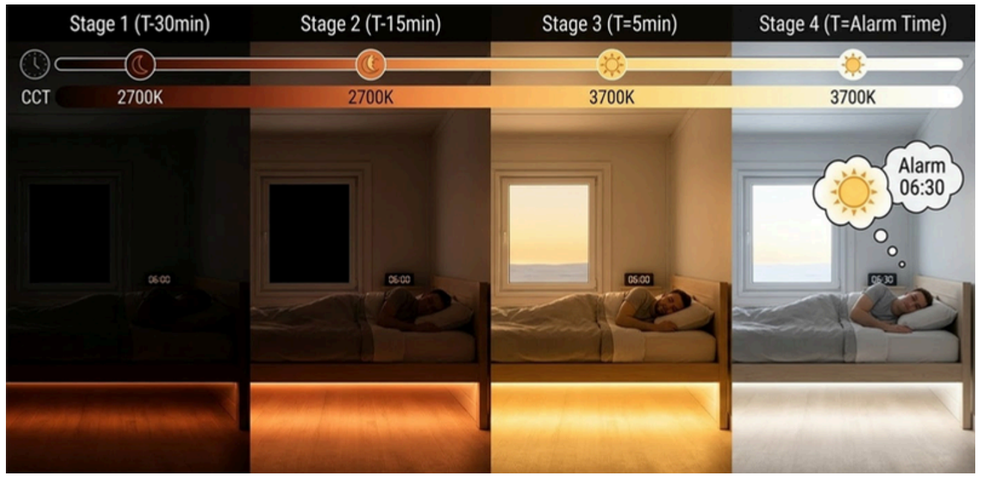
Conclusion
Manual Overrides = Priority 1 User Comfort.
AI Brightness = Priority 2 Health & Safety

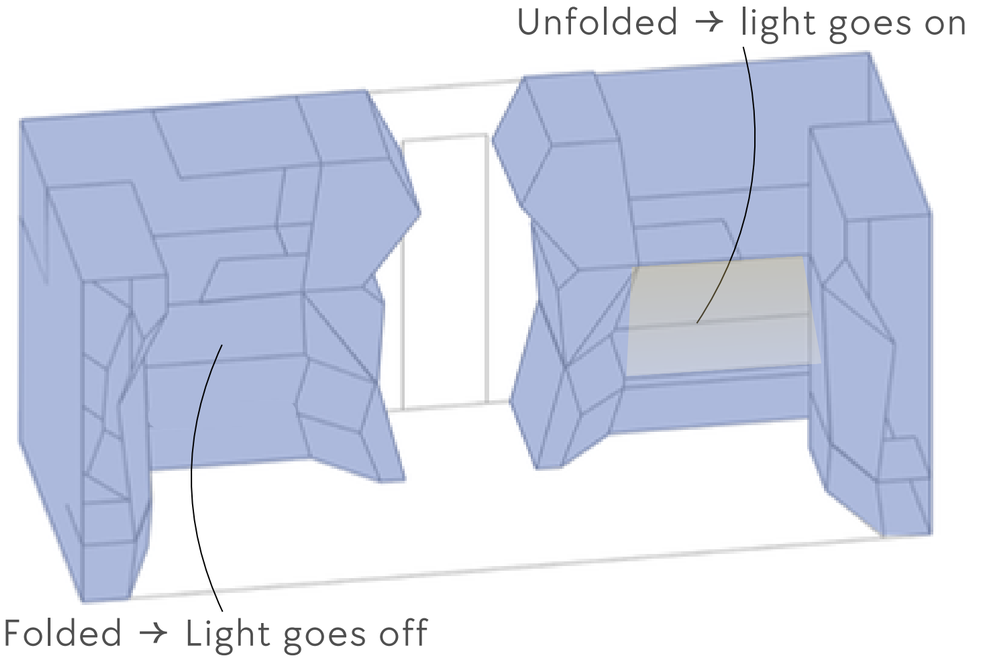
LIGHTING AND AI |CONTROL SYSTEMS

Layer 1: Identity
- Key: smartwatch (who is in the room?)
- Personal preferences: CCT & Lux
- Circadian: sunrise simulation (30 min)

Layer 2: Activity
- Eyes: computer vision
- Intent: Detects when the desk is unfold to activate a 'Work' scene
- Stress-relief lighting (heart rate)

Layer 3: Context
- Exterior sync: actic weather data
- Polar night: increases the light quality to mimic sunlight (High CRI)
- Midnight sun: digital darkness (melatonin support)





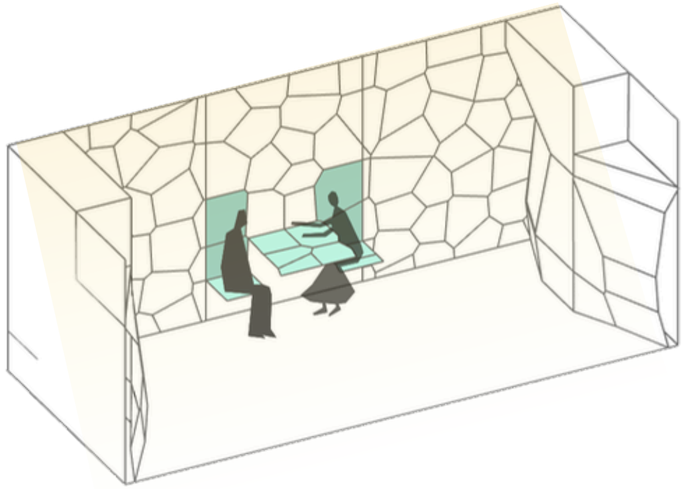
LIGHTING AND AI | AMBIENT LIGTHTING

Two Modes: Vision-Driven Logic
Computer Vision recognizes the furniture configuration to trigger the correct mode automatically.

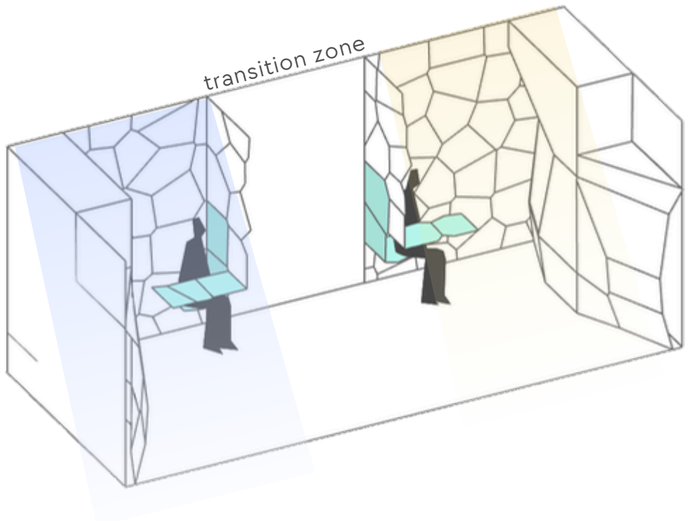
- **Collective Mode** (Table Centered):
  - Trigger: Table in the center (detected by CV).
  - Collective Balancing. The AI calculates an average between both users.
  - All lighting zones are synced to for example a warm 3000K setting for shared activities.

- **Private Mode** (Table Rotated or Split):
  - Trigger: Table split or rotated.
  - The AI divides the container into two personalized "light bubbles."
  - These bubbles follow the residents through the space using UWB (Apple Watch) tracking.

Collective mode



Private mode

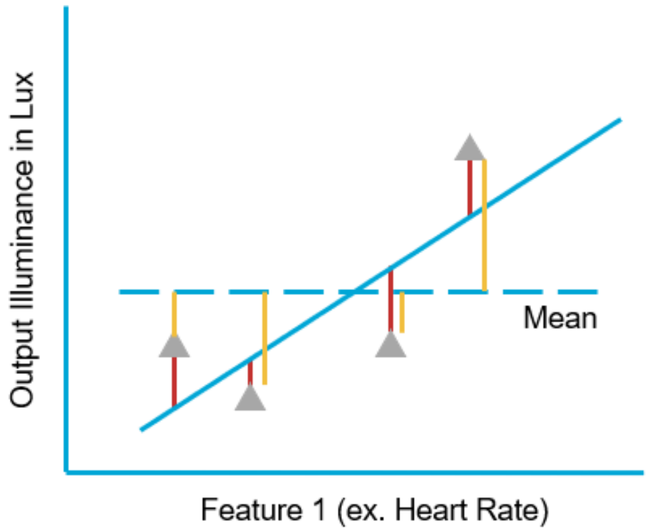


TUTORIAL 27/02/26 OF JUPITER NOTEBOOK

The values the Jupiter Notebook model produces is the prediction of what the lux should be according to the model. This model uses the technique of neural networks.

Machine learning, unlike AI, infers patterns from data while AI needs the patterns as an input.

To implement the control systems we used machine learning to control and predict the lighting systems, this was done by a Jupyter Notebook code with neural networks.



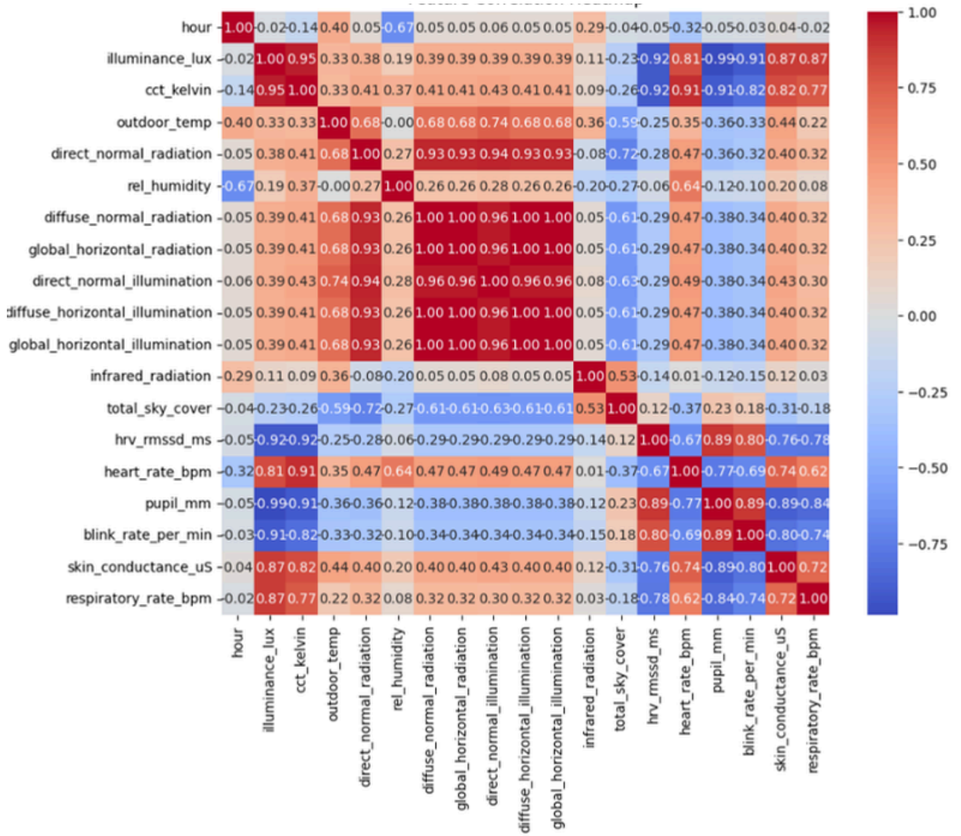
SUPERVISED LEARNING

- Features are the input variables, possible features;
  - **Weather features;** outdoor_temp, direct_normal_radiation, rel_humidity, diffuse_normal_radiation, global_horizontal_radiation, infrared_radiation, direct_normal_illumination, diffuse_horizontal_illumination, global_horizontal_illumination, total_sky_cover.
  - **Physological features;** hrv_rmssd_ms, heart_rate_bpm, pupil_mm, blink_rate_per_min, skin_conductance_uS, respiratory_rate_bpm.
- Labels are the output values, in this case the predicted illuminance_lux and cct_kelvin

SELECTING THE FEATURES AND LABELS: BALANCING ACCURACY OF MODEL WITH RISK OF OVERFITTING

- Choosing and grouping features.
  - Features with high correlation >0.8 with each other may be redundant, so they can be grouped or dropped.
  - Features with high correlation with labels are likely strong predictors.
- With cross-validation we are testing the overfitting, if results are similar to the test score, that means low overfitting.

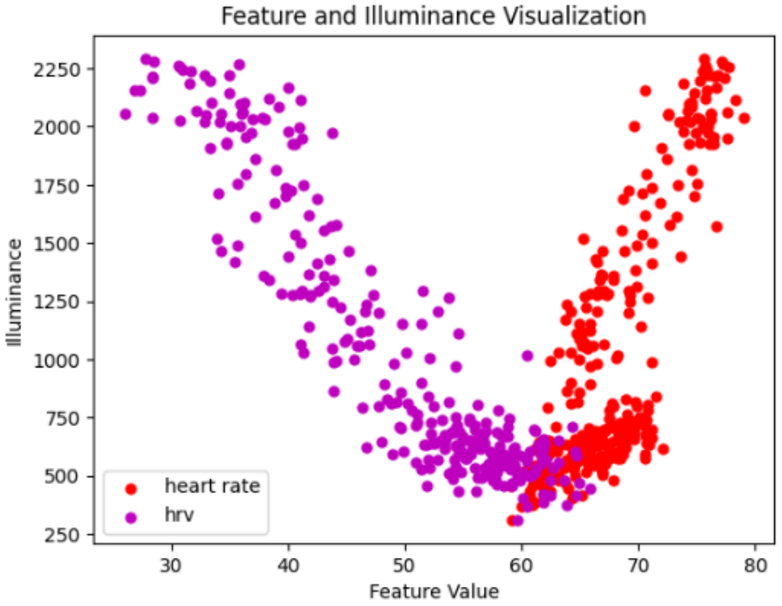
Feature correlation heatmap



MACHINE LEARNING | TRAINING

FEATURE GROUPING

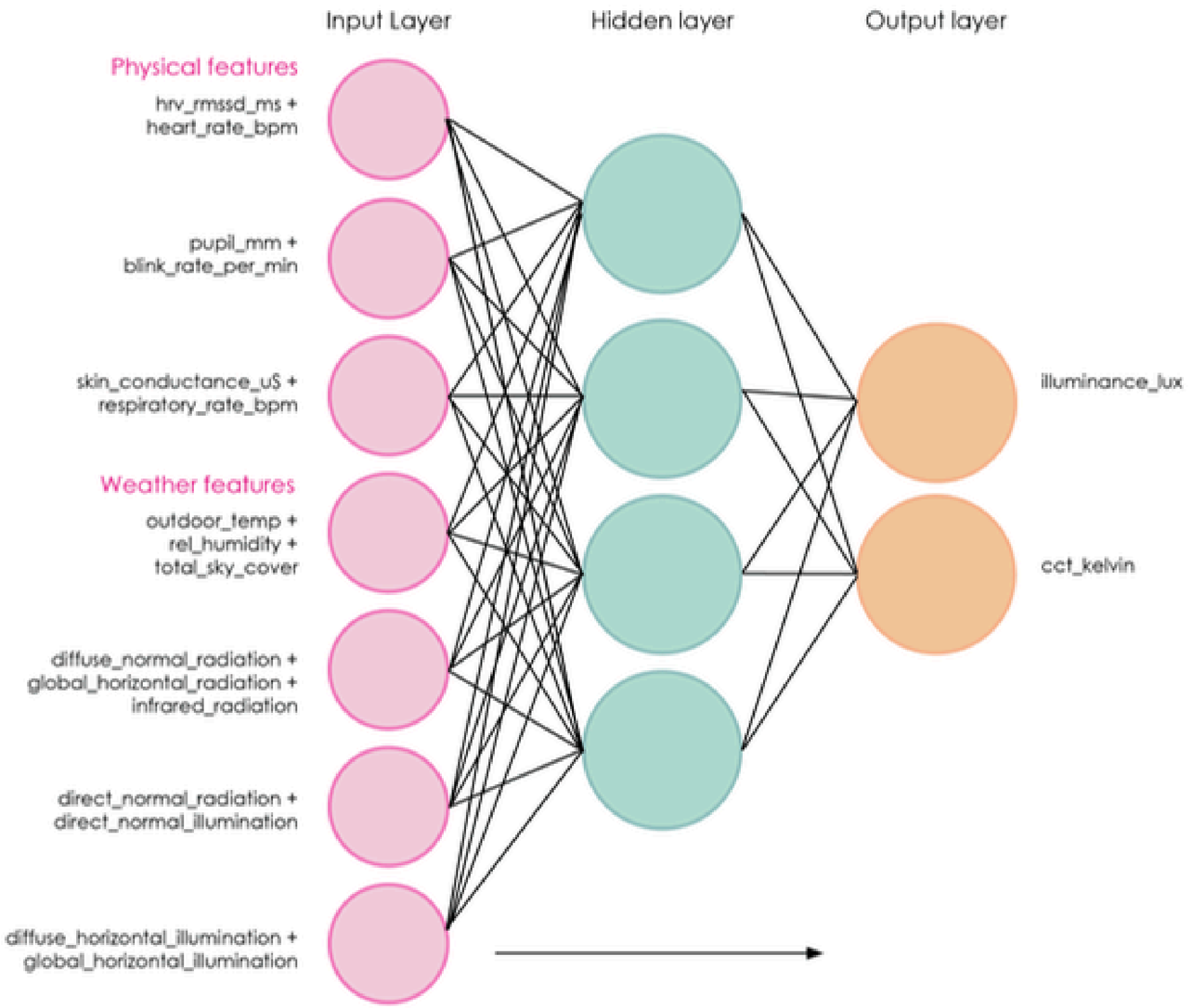
- For the weather features e.g. I found strong correlations, which can be grouped together to reduce redundancy: Direct radiation and direct illumination (0.94) and diffuse horizontal and global horizontal illumination (0.88)
- For the physiological features e.g. I found inversely correlated features, one of these can be used as a representative feature. HRV and heart rate (0.85).



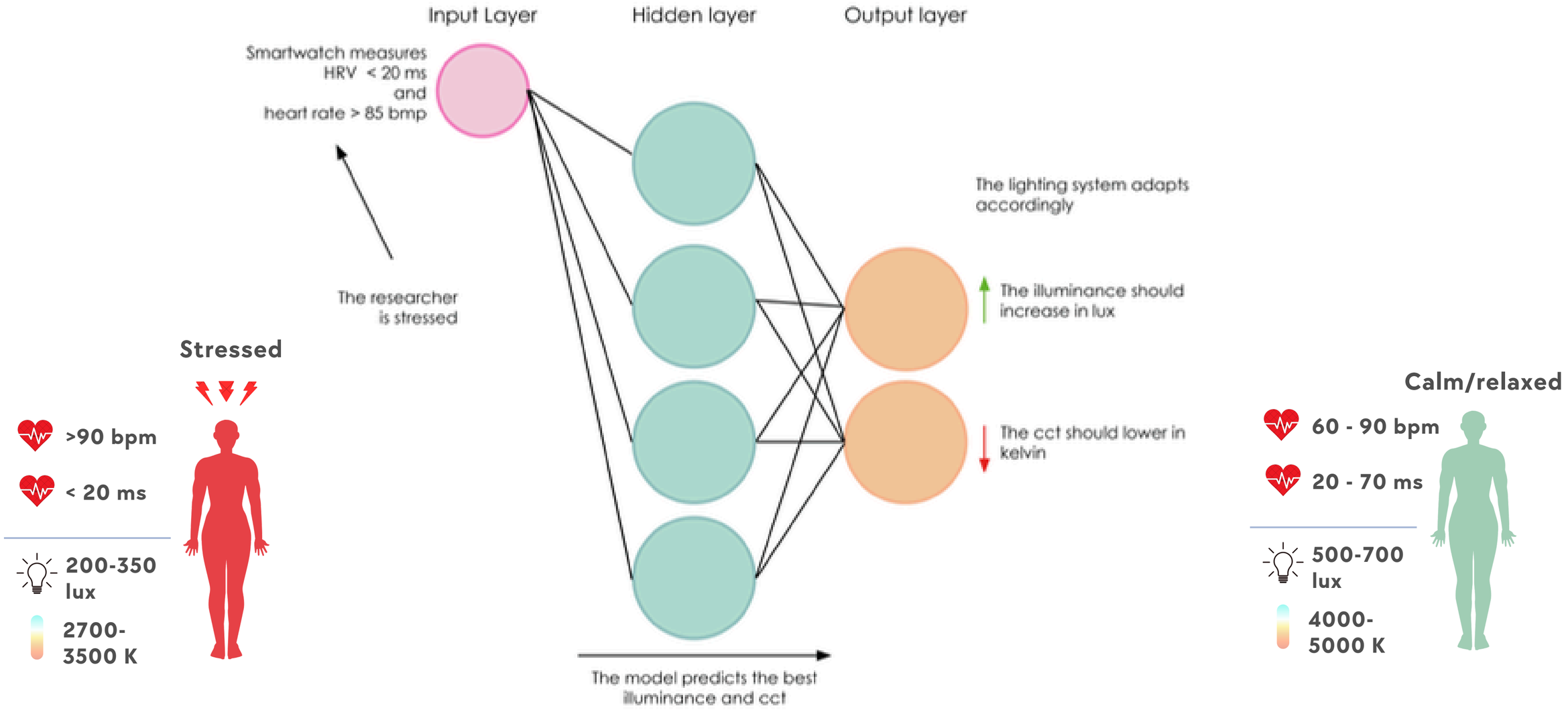
EVALUATING MODEL PERFORMANCE

- **R-square** is used to evaluate how well the model represents the data (the variance of the mean). For example, if R-square is 80%, then the model can express 80% of the variability.
- Error functions such as **RMSE** and **MAE** provide information about how far off the estimation is from the actual value. RMSE penalizes large errors and MAE takes the average. Both of the scores are relative to the scale of the dataset.
- Performance of the first model vs second model trained with adjusted features;
- R-square = 0.13752631245104485 → 0.6972536094819399,
- RMSE = 547.2232257652937 → 401.7306132398937,
- MAE = 463.33269614523095 → 322.292021438062
- Conclusion; clear improvement of the model performance.

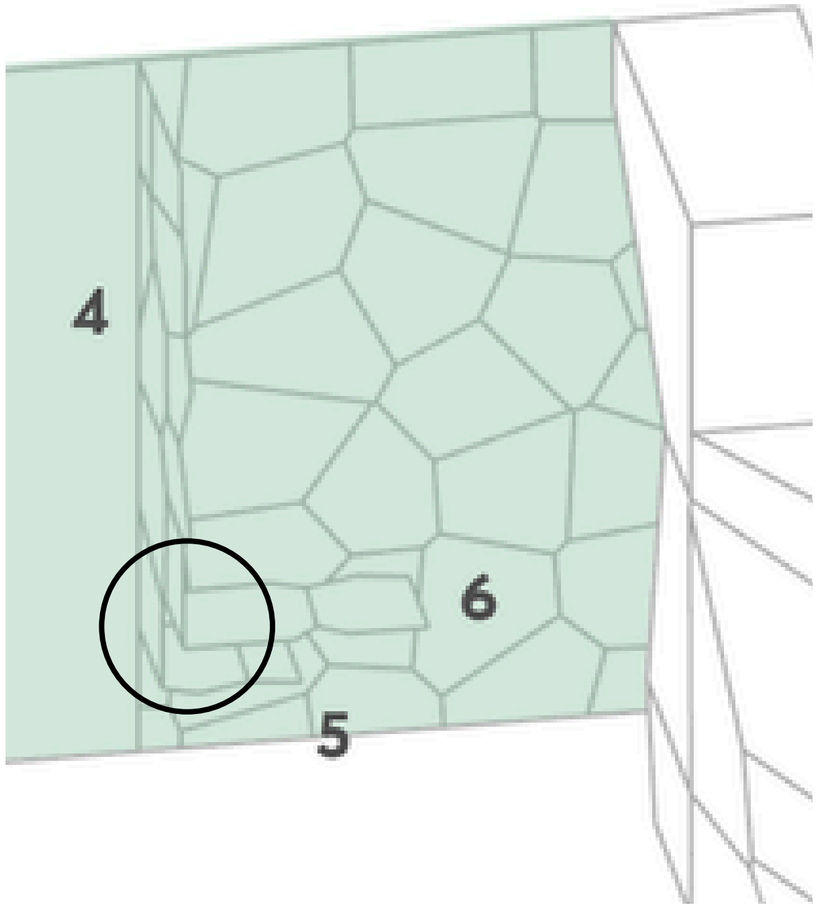
MACHINE LEARNING | TRAINING - FEATURE GROUPS



MACHINE LEARNING | TRAINING - EXAMPLE



23 CHOOSEN FRAGMENT



A piece of the kinetic wall:

Lounge chair/DIning chair

Thank you for your attention !