TÉCNICO LISBOA

TOWARDS LIGHTING OPTIMIZATION

A PERFORMANCE-BASED APPROACH

INÊS PEREIRA

SUPERVISOR | ANTÓNIO LEITÃO

MOTIVATION

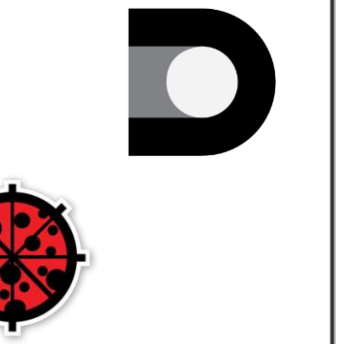
KOLDING CAMPUS

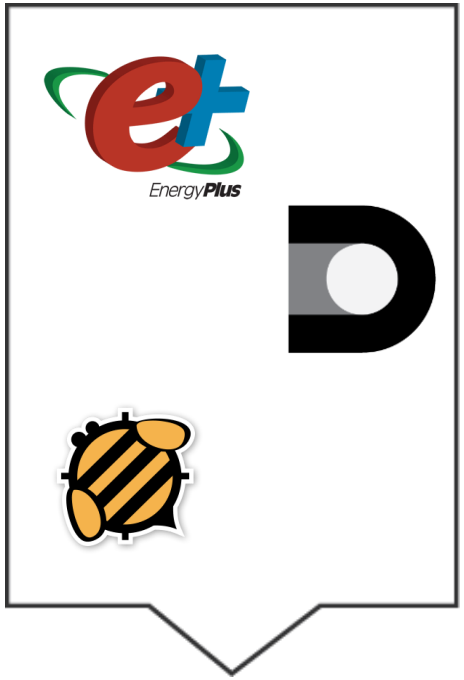
HENNING LARSEN ARCHITECTS

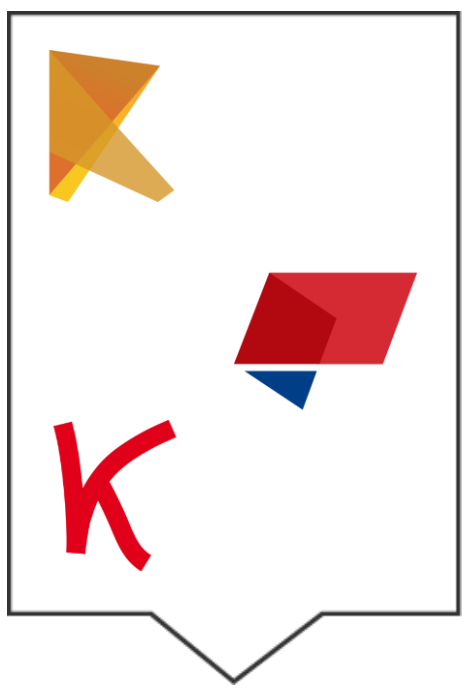
ANALYSIS TOOLS

ANALYSIS TOOLS

Radiance

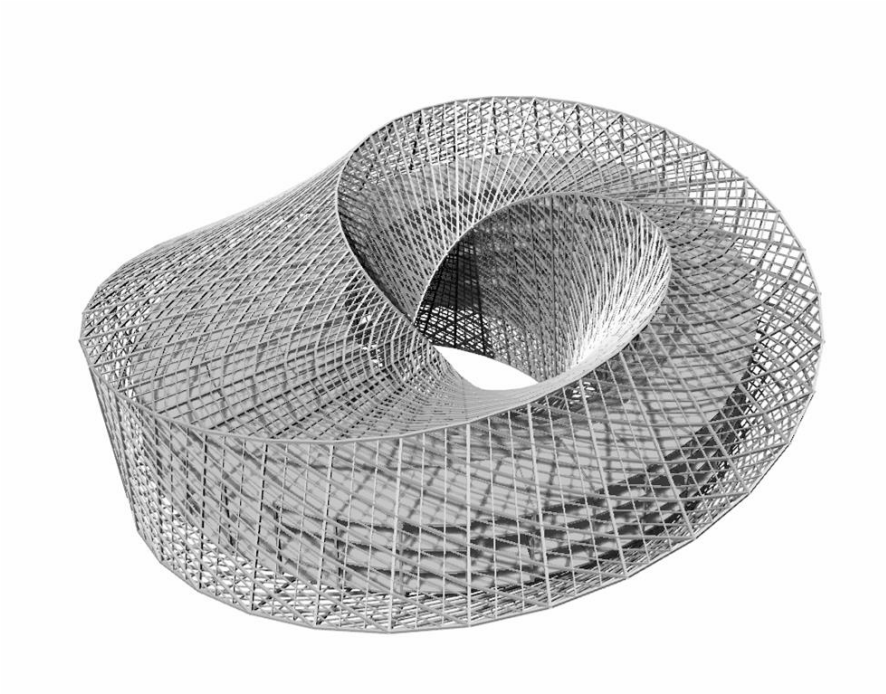






ANALYTICAL MODEL

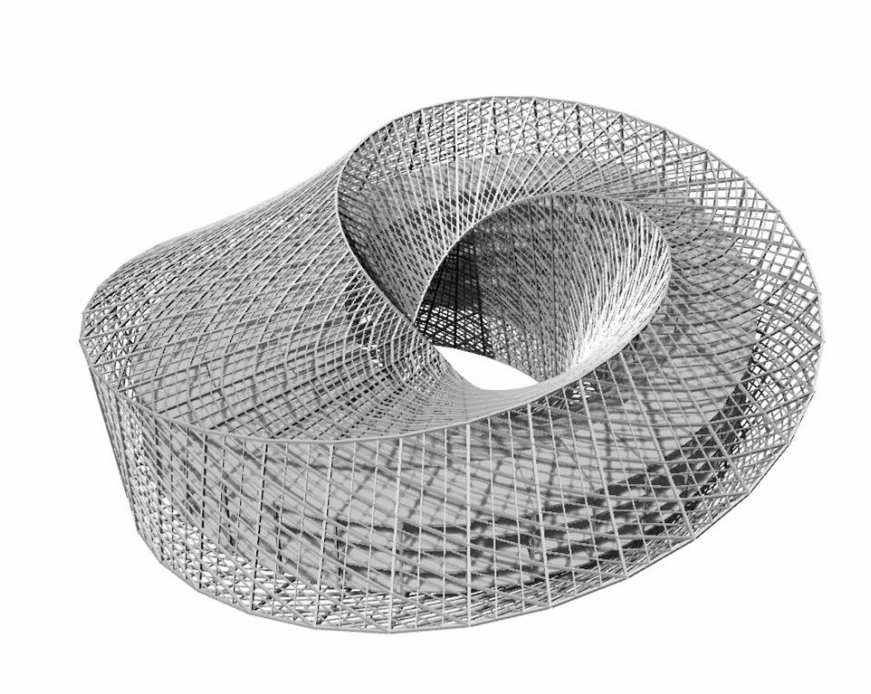
ANALYTICAL MODEL



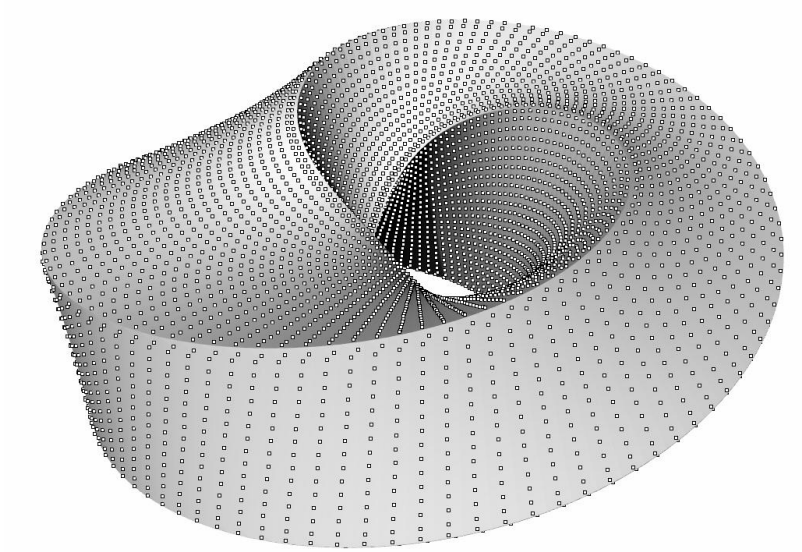
3D model

Castelo-Branco, R., & Leitão, A. (2017). Integrated Algorithmic Design: A Single-Script Approach for Multiple Design Tasks. (35th eCAADe)

ANALYTICAL MODEL



3D model



analytical
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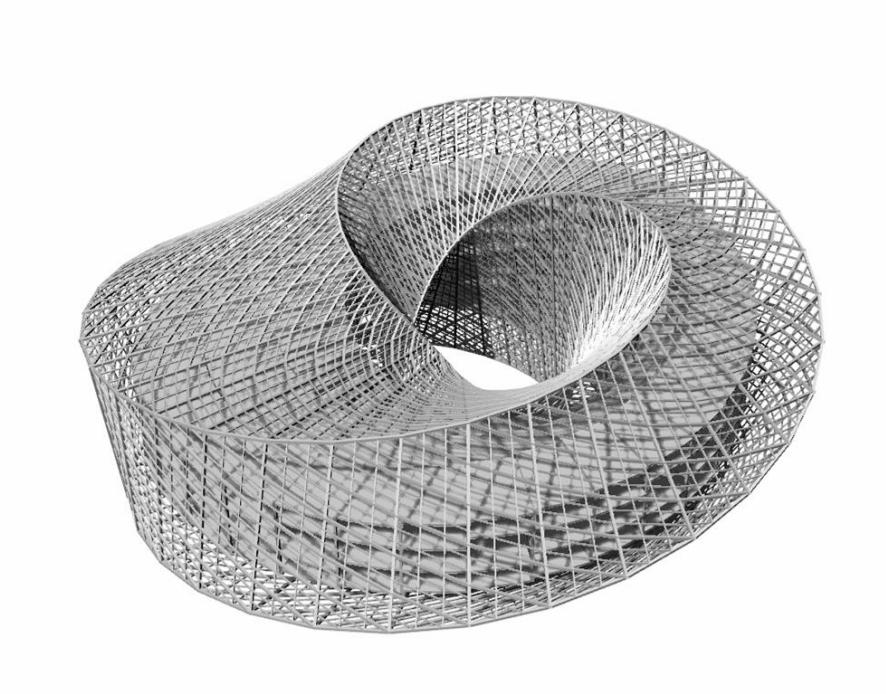
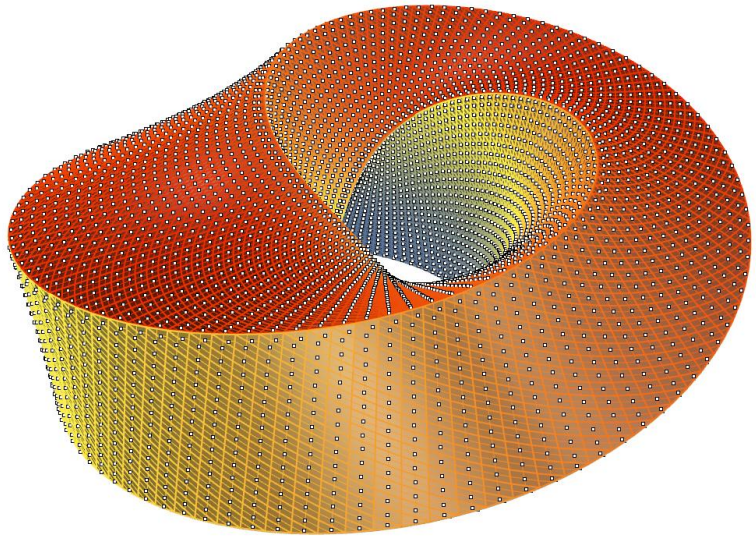


3D model



lighting
simulation

Castelo-Branco, R., & Leitão, A. (2017). Integrated Algorithmic Design: A Single-Script Approach for Multiple Design Tasks. (35th eCAADe)

PERFORMANCE-BASED DESIGN

LONDON CITY HALL

FOSTER + PARTNERS


https://www.bayut.com/mybayut/modern-architecture-spotlight-zaha-hadid-architect/

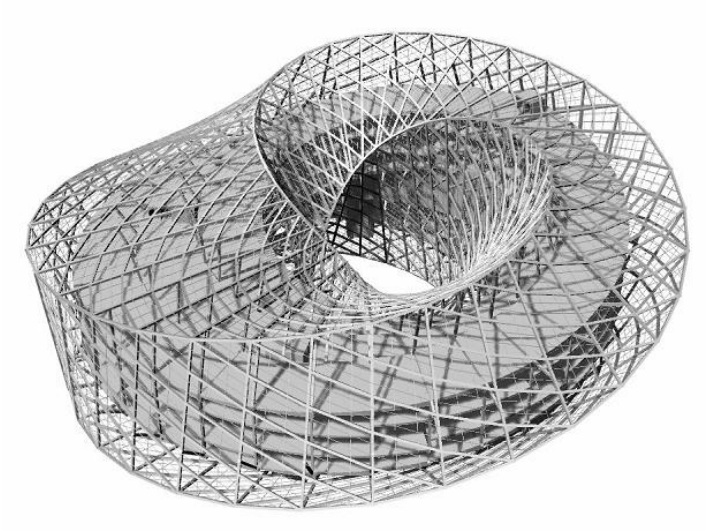
ALGORITHMIC DESIGN AND ANALYSIS

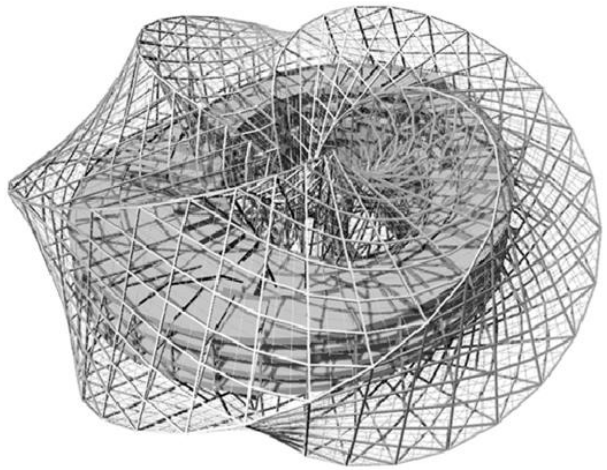
HEYDAR ALIYEV CENTER

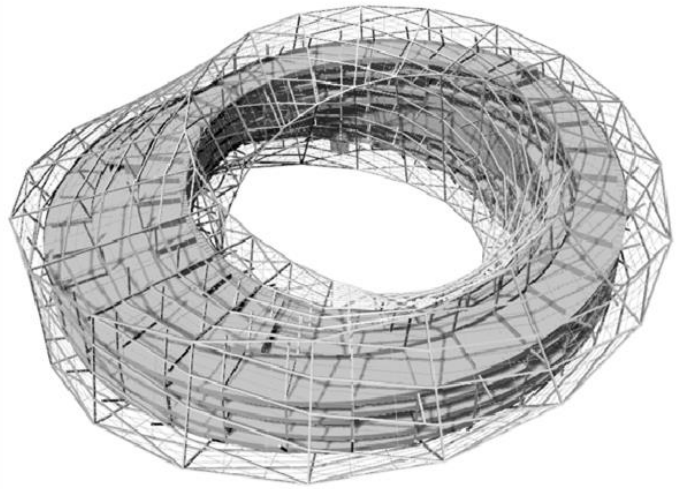
ZAHA HADID ARCHITECTS

ALGORITHIMIC DESIGN AND ANALYSIS

PARAMETRIC MODEL







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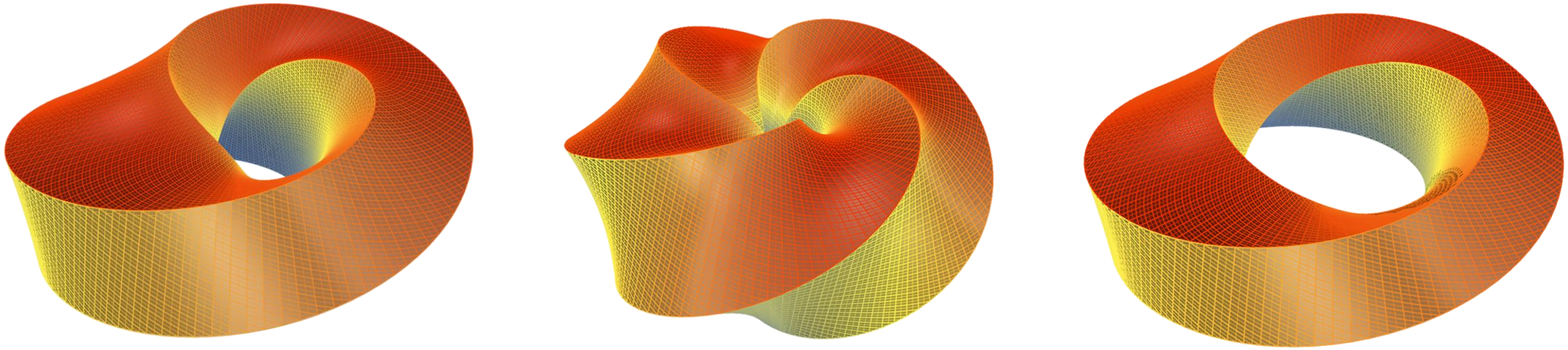
ALGORITHIMIC DESIGN AND ANALYSIS

ANALYTICAL MODEL + ANALYSIS

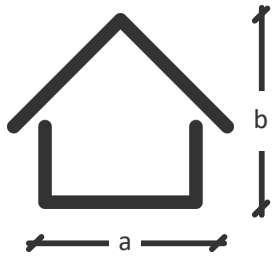


Castelo-Branco, R., & Leitão, A. (2017). Integrated Algorithmic Design: A Single-Script Approach for Multiple Design Tasks. (35th eCAADe)

OBJECTIVES

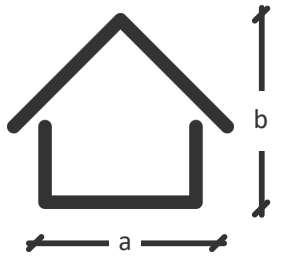
- KOSHINO HOUSE
- TADAO ANDO

OBJECTIVES



parametric
model

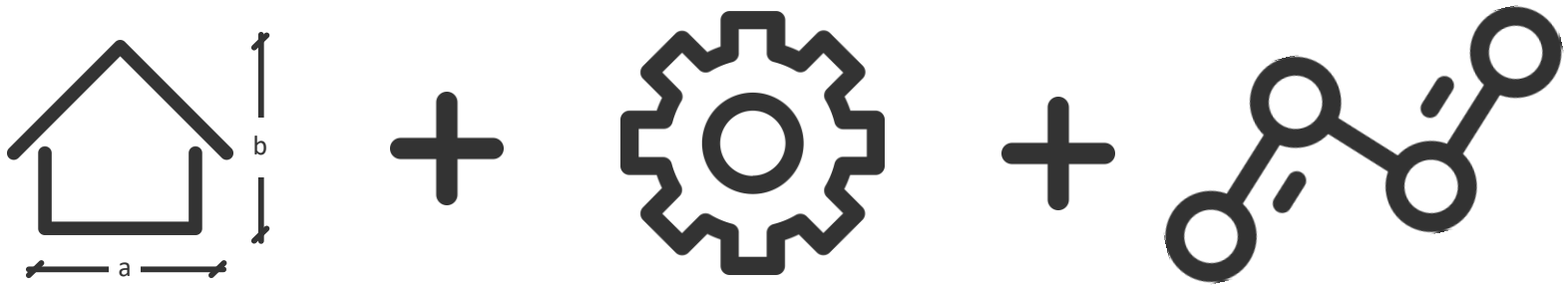
OBJECTIVES



parametric
model

analysis
tools

OBJECTIVES

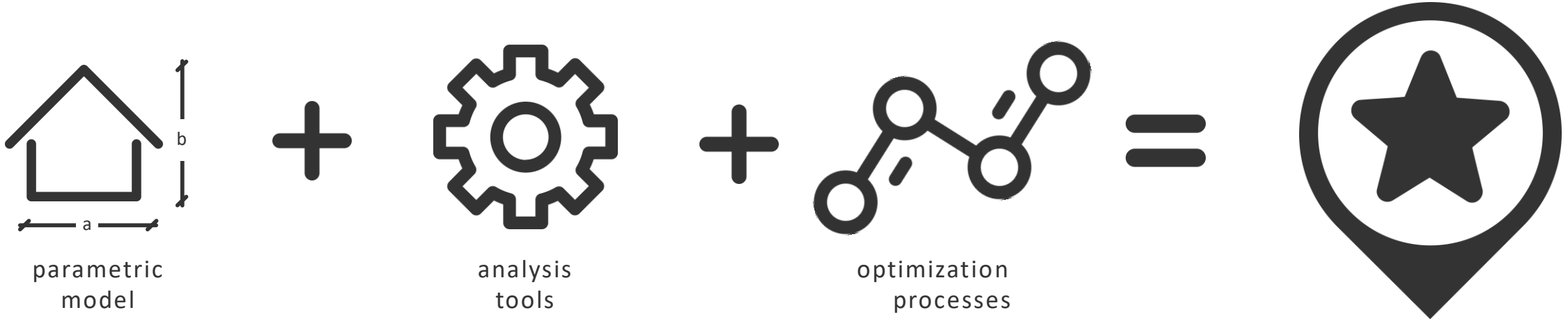


parametric model

analysis tools

optimization processes

OBJECTIVES



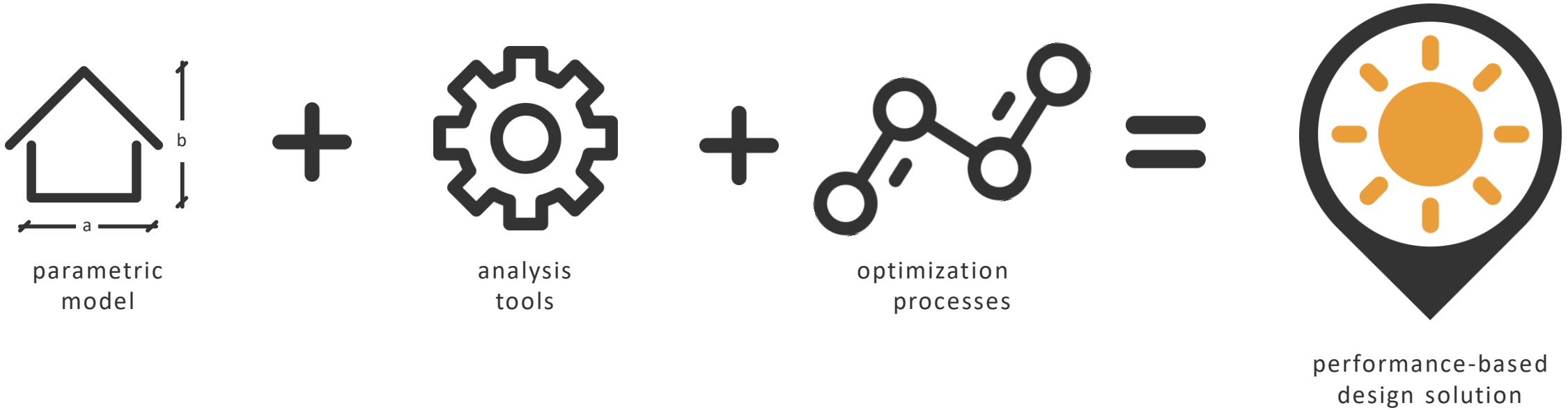
parametric model

analysis tools

optimization processes

performance-based design solution

OBJECTIVES



parametric model

analysis tools

optimization processes

performance-based design solution

METHODOLOGY

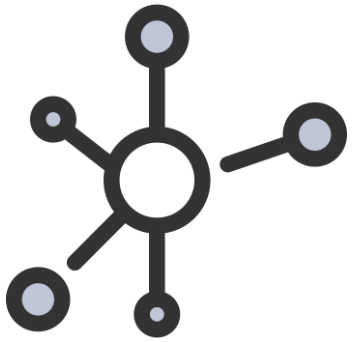
https://www.freepik.com/free-photo/business-team-working-office-worker-concept_2862206.htm

METHODOLOGY

SENSITIVITY ANALYSIS

METHODOLOGY

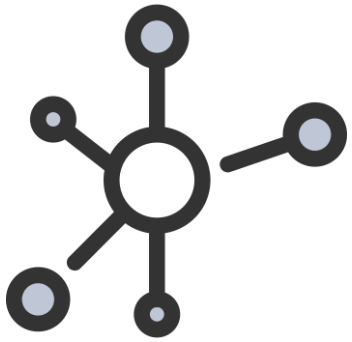
SENSITIVITY ANALYSIS



establish
correlations

METHODOLOGY

SENSITIVITY ANALYSIS



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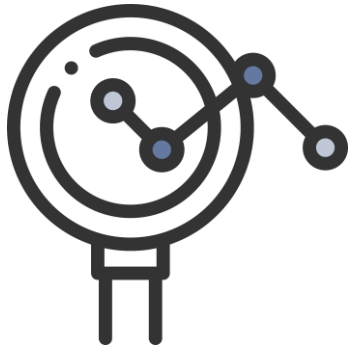
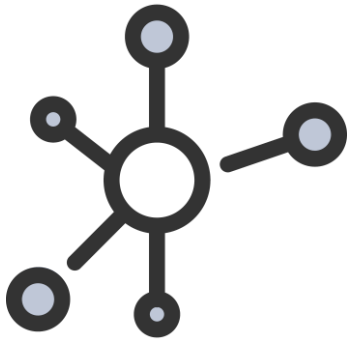


inform
decisions

METHODOLOGY

SENSITIVITY ANALYSIS



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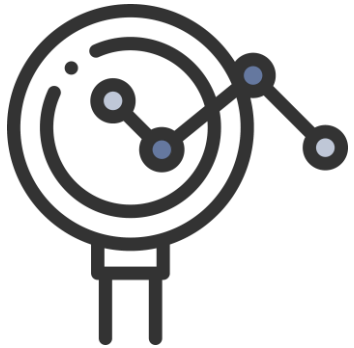

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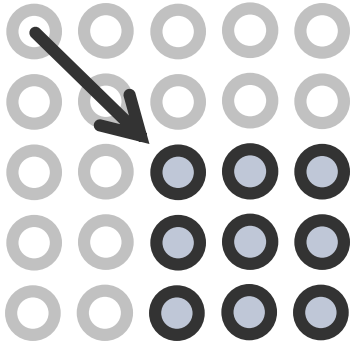


reduce
design space

METHODOLOGY

MULTI-OBJECTIVE WORKFLOW

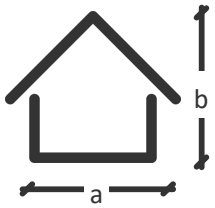
METHODOLOGY

MULTI-OBJECTIVE WORKFLOW

architect

METHODOLOGY

MULTI-OBJECTIVE WORKFLOW



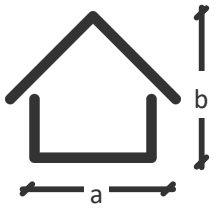
parametric
model

architect

METHODOLOGY

MULTI-OBJECTIVE WORKFLOW

architect



parametric model

analysis 1

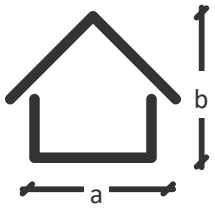
analysis 2

analysis …

METHODOLOGY

MULTI-OBJECTIVE WORKFLOW

architect



parametric model

optimization algorithm

analysis 1

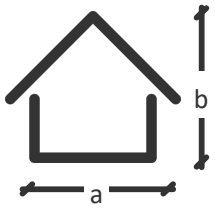
analysis 2

analysis …

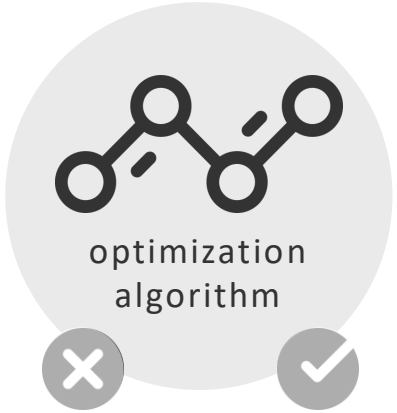
METHODOLOGY

MULTI-OBJECTIVE WORKFLOW

architect



parametric model



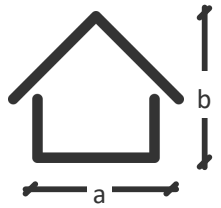
analysis 1

analysis 2

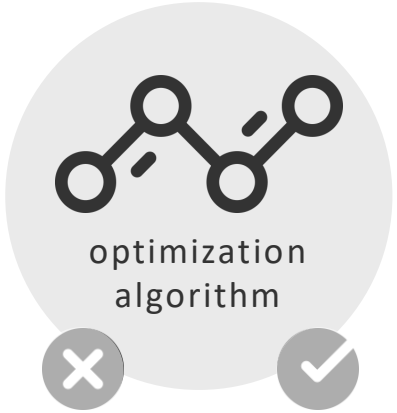
analysis …

METHODOLOGY

MULTI-OBJECTIVE WORKFLOW



parametric model



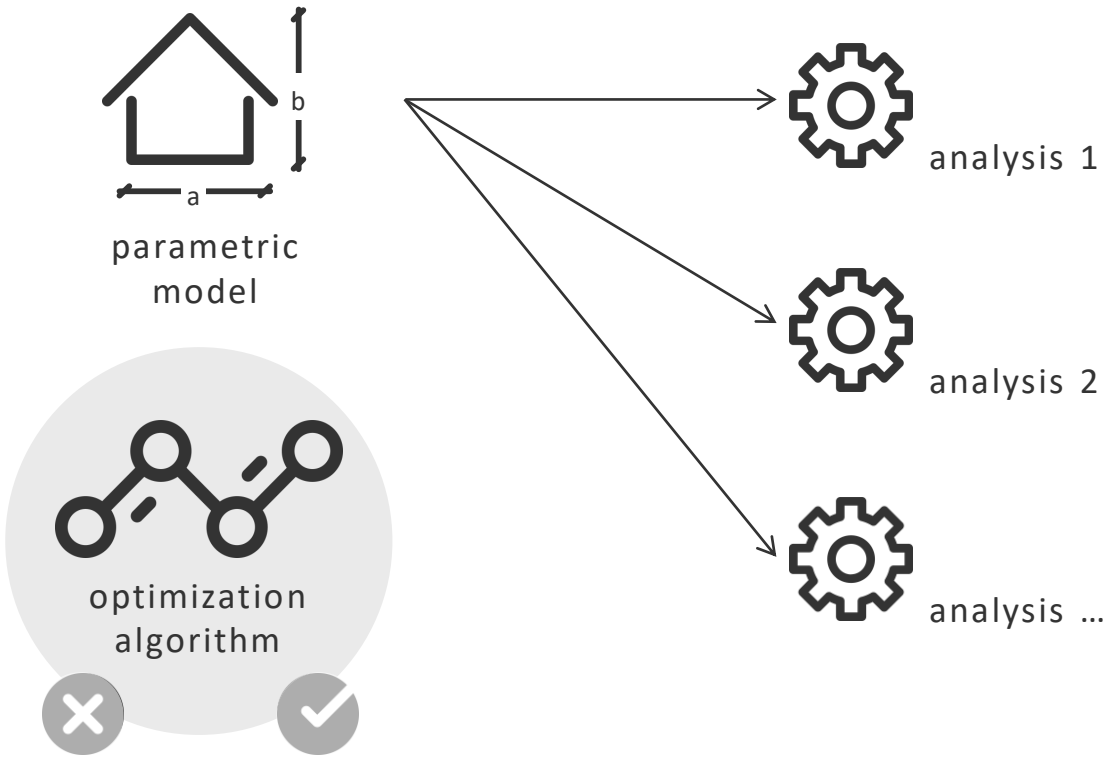
analysis 1

analysis 2

analysis …

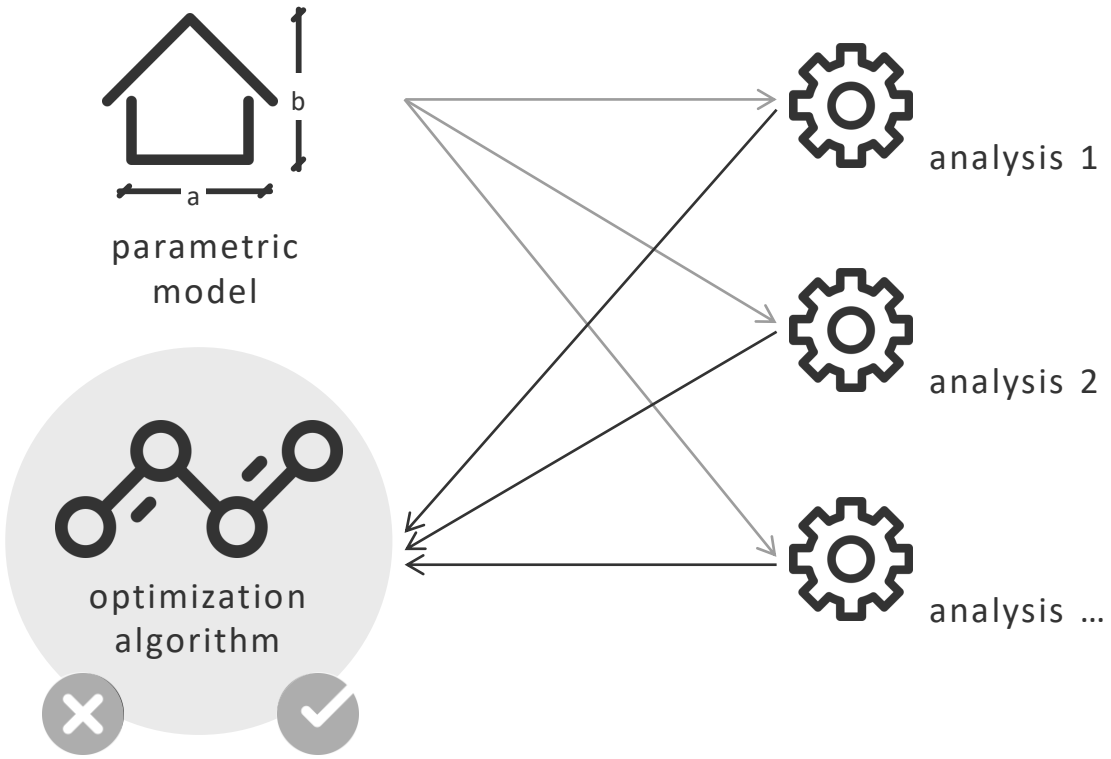
METHODOLOGY

MULTI-OBJECTIVE WORKFLOW



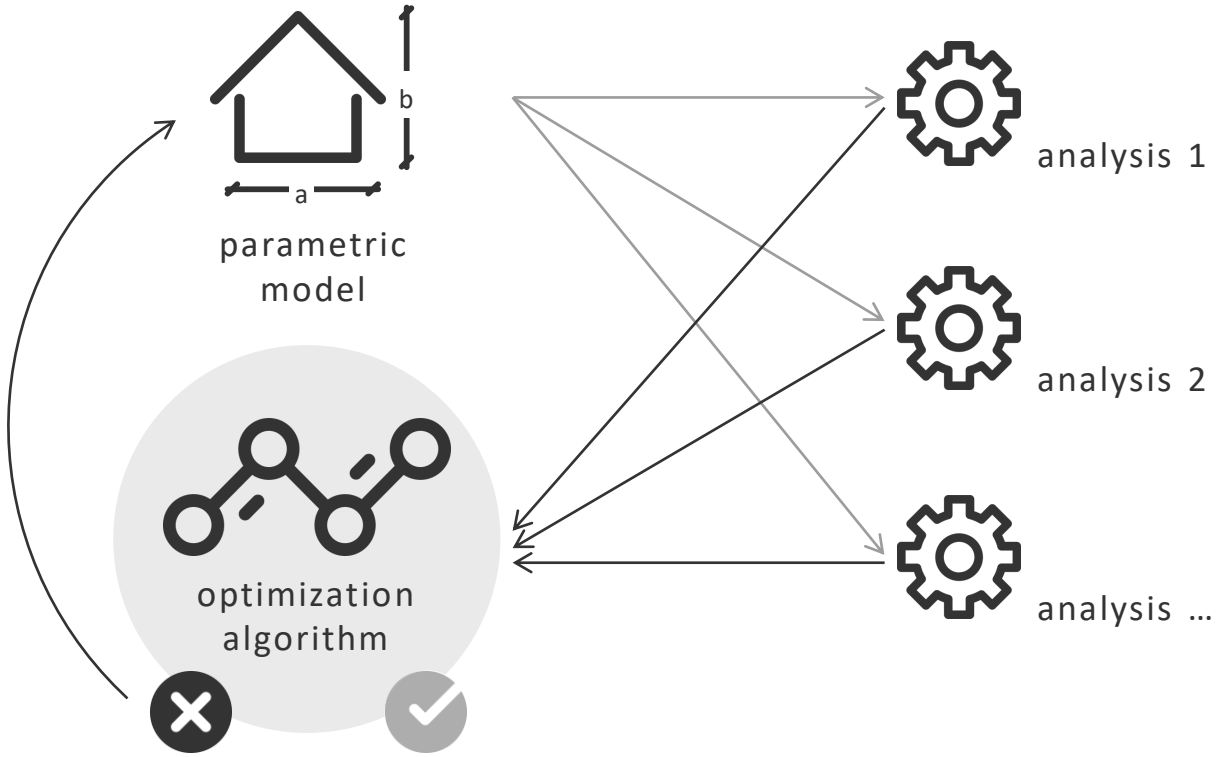
METHODOLOGY

MULTI-OBJECTIVE WORKFLOW



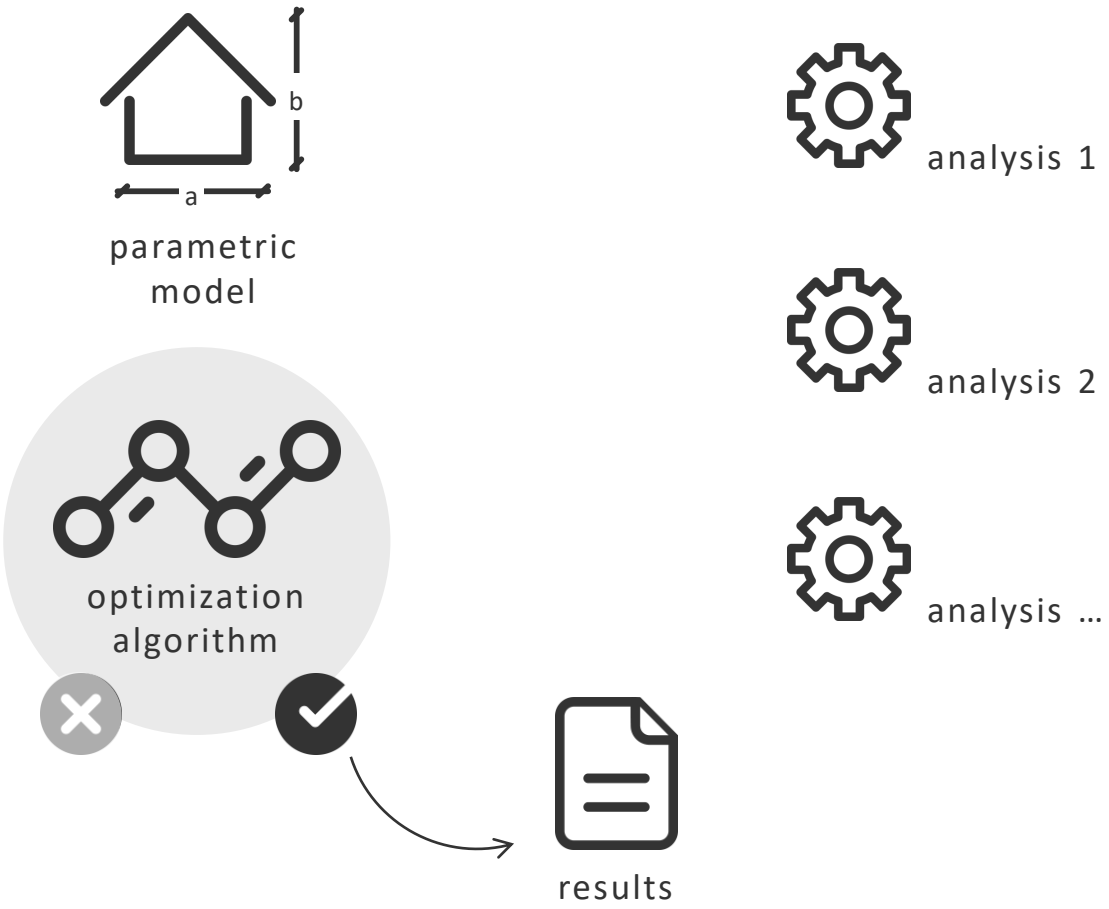
METHODOLOGY

MULTI-OBJECTIVE WORKFLOW



METHODOLOGY

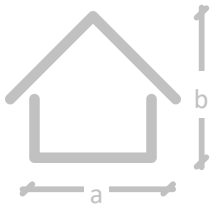
MULTI-OBJECTIVE WORKFLOW



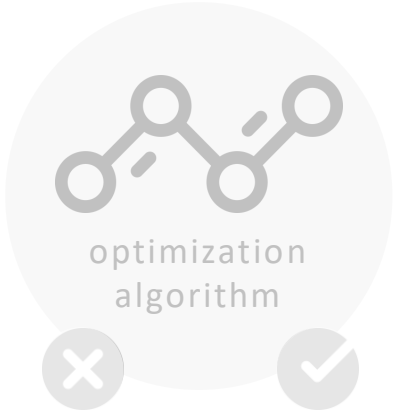
METHODOLOGY

MULTI-OBJECTIVE WORKFLOW

architect



parametric model



analysis 1

analysis 2

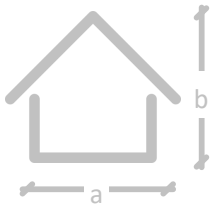
analysis …

results

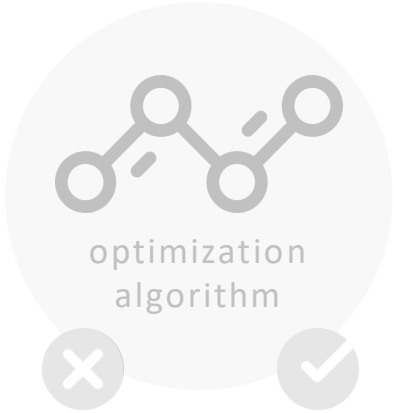
METHODOLOGY

MULTI-OBJECTIVE WORKFLOW

architect



parametric model



analysis 1

analysis 2

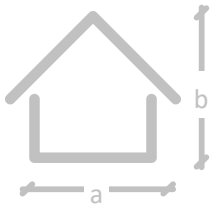
analysis …

visualization

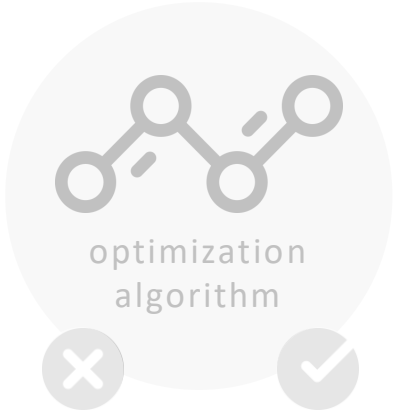
METHODOLOGY

MULTI-OBJECTIVE WORKFLOW

architect



parametric model



analysis 1

analysis 2

analysis …

visualization

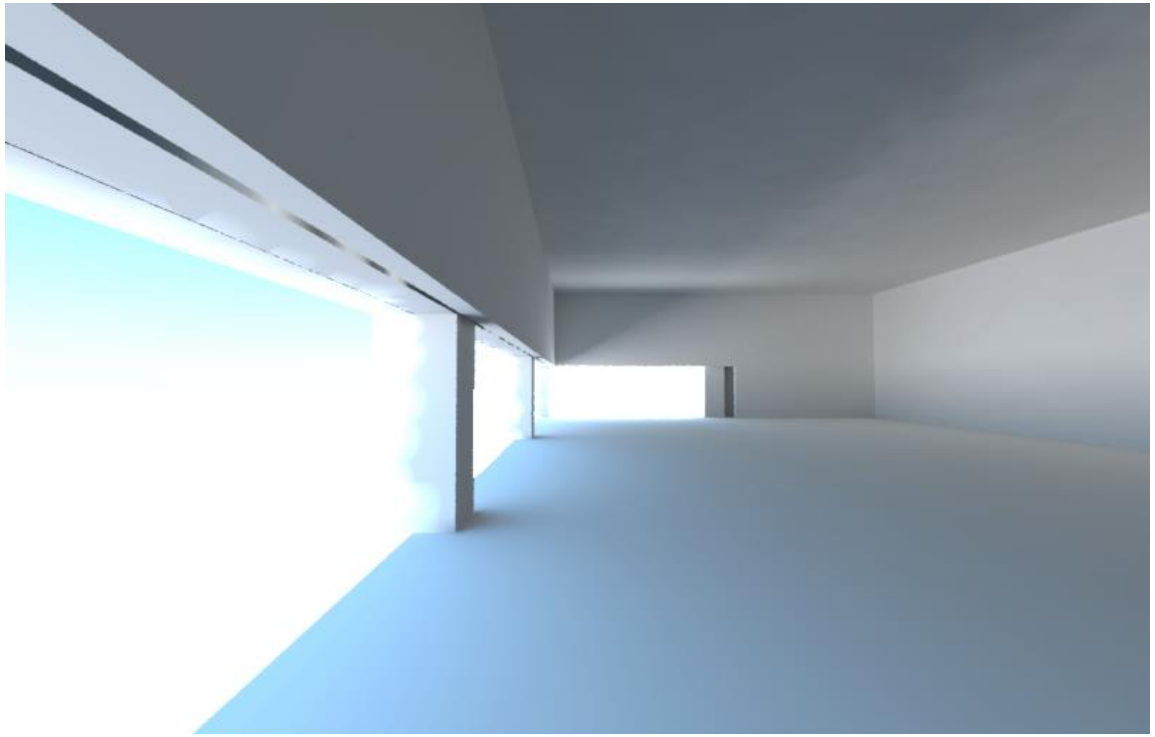
evaluate solutions

CASE STUDY

BLACK PAVILION

RENOVATION BY
ATELIER DOS REMÉDIOS

CASE STUDY



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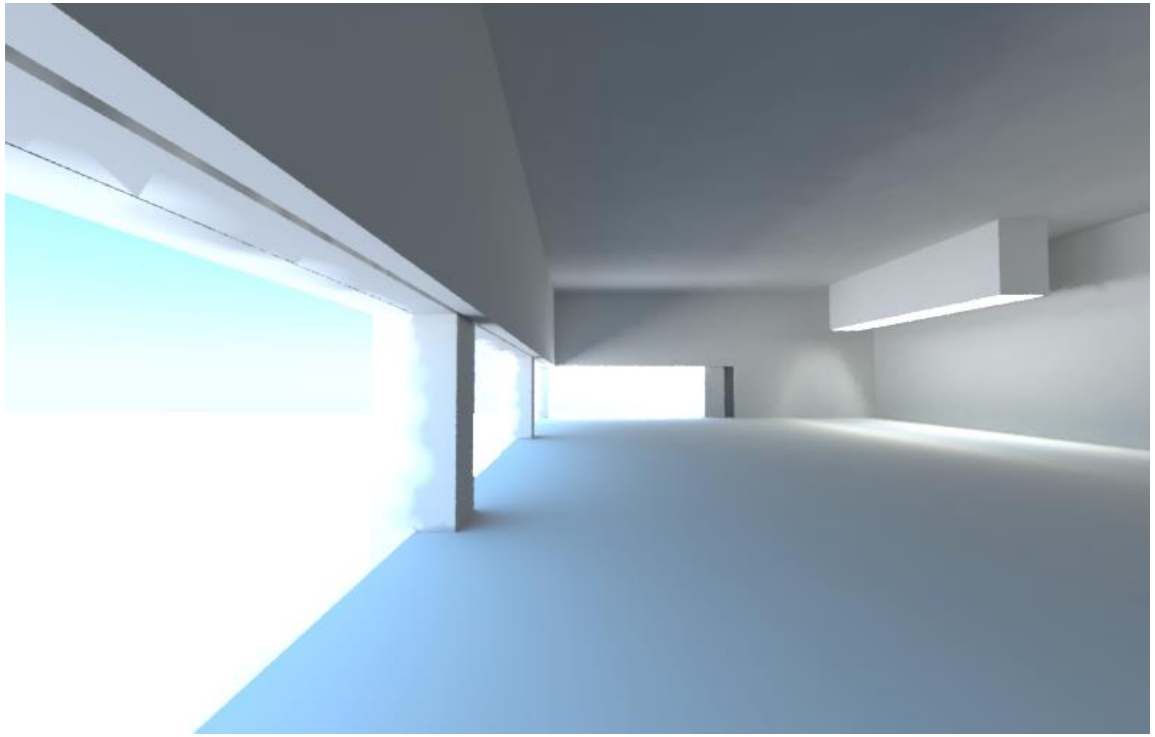
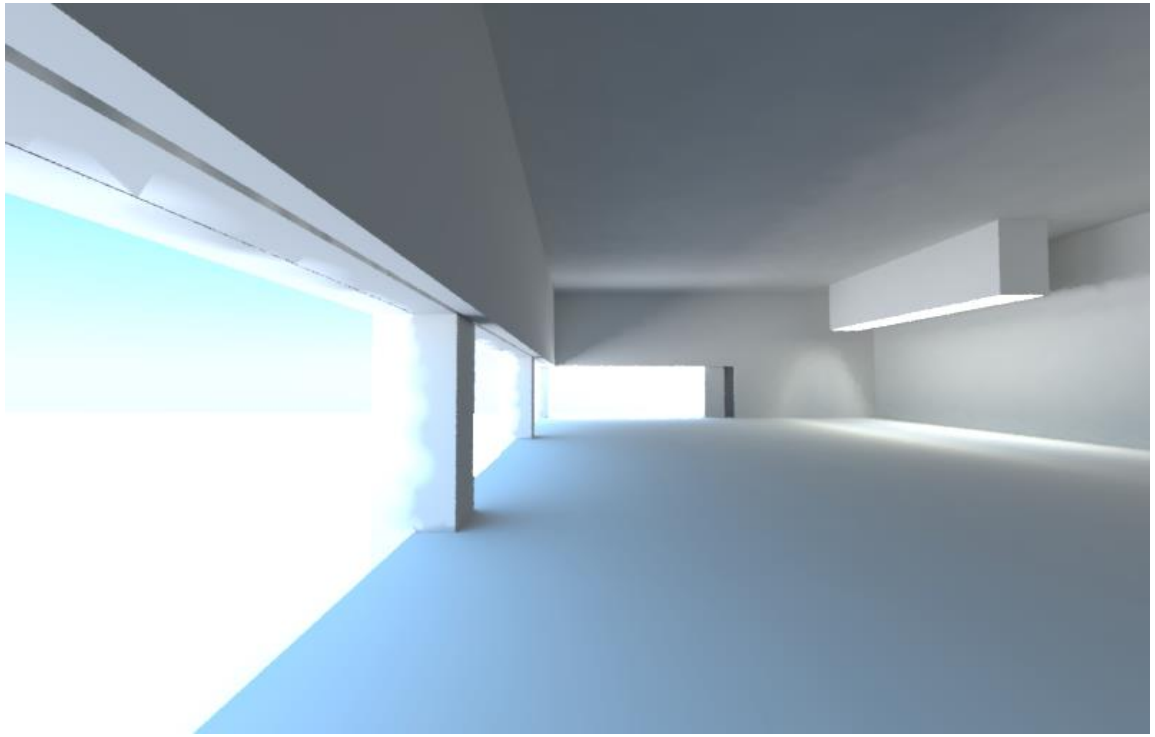
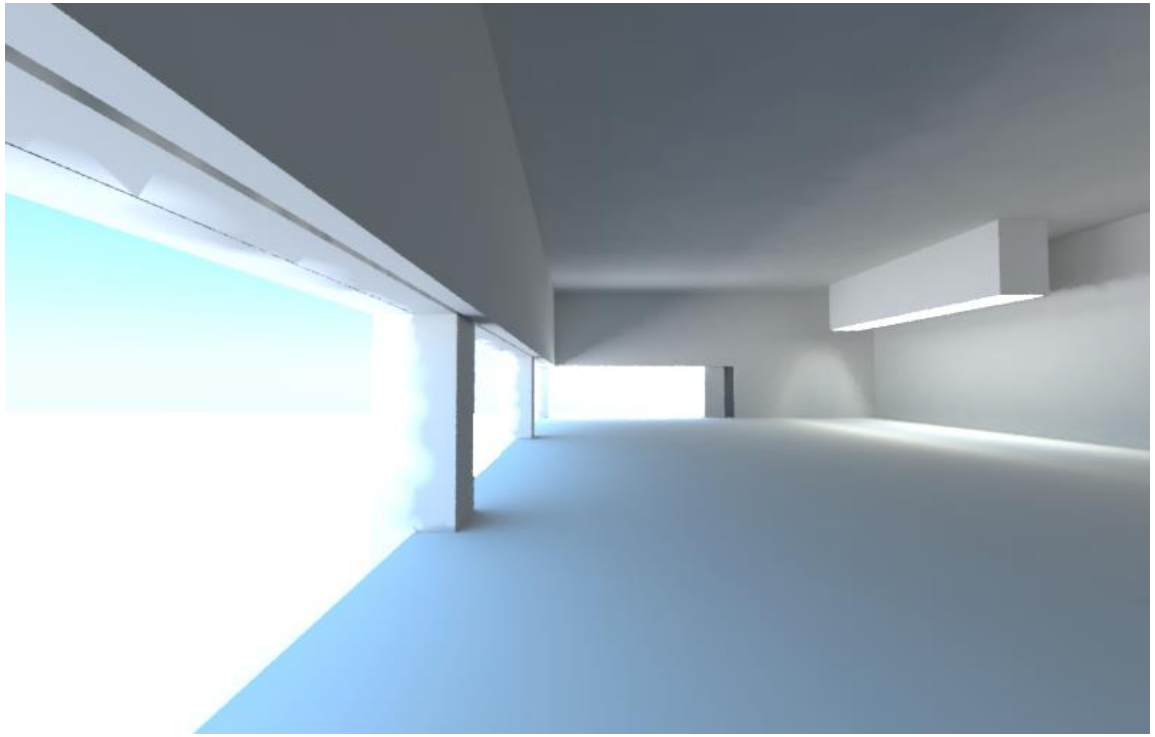


CASE STUDY



VARIABLE PARAMETERS

CASE STUDY



VARIABLE PARAMETERS

skylight height

skylight length

skylight width

skylight and curtain-wall material

DAYLIGHT OPTIMIZATION

DAYLIGHT METRIC

SPATIAL USEFUL DAYLIGHT ILLUMINANCE [sUDI]

DAYLIGHT METRIC

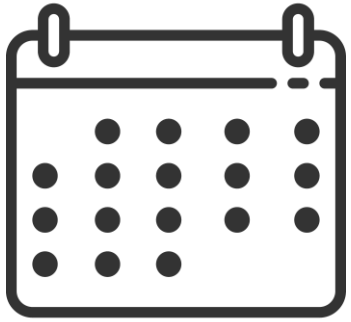
SPATIAL USEFUL DAYLIGHT ILLUMINANCE [sUDI]

climate-based

DAYLIGHT METRIC

SPATIAL USEFUL DAYLIGHT ILLUMINANCE [sUDI]

climate-based

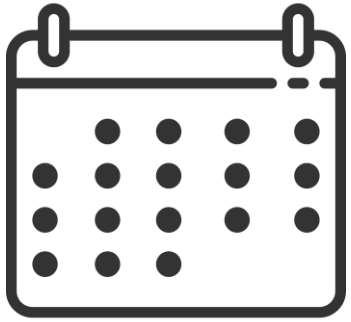


annual

DAYLIGHT METRIC

SPATIAL USEFUL DAYLIGHT ILLUMINANCE [sUDI]

climate-based



annual

occupancy schedule

DAYLIGHT REQUIREMENTS

ILLUMINANCE VALUES

DAYLIGHT REQUIREMENTS

ILLUMINANCE VALUES

category	material classification	example of materials	lighting illuminance	limiting annual exposure
I	insensitive	metal, stone, glass, ceramic	no limit	no limit
II	low sensitivity	canvas, frescos, wood, leather	200 lux	600 000 lux h/yr
III	medium sensitivity	watercolor, pastel, various paper	50 lux	150 000 lux h/yr
IV	high sensitivity	silk, newspaper, sensitive pigments	50 lux	15 000 lux h/yr

source: CIE TC 3-22 ”Museum lighting and protection against radiation damage”

DAYLIGHT REQUIREMENTS

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sUDI
ILLUMINANCE RANGE

from 0 lux to 220 lux

DAYLIGHT REQUIREMENTS

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sUDI
ILLUMINANCE RANGE

from 0 lux to 220 lux

CURRENT sUDI

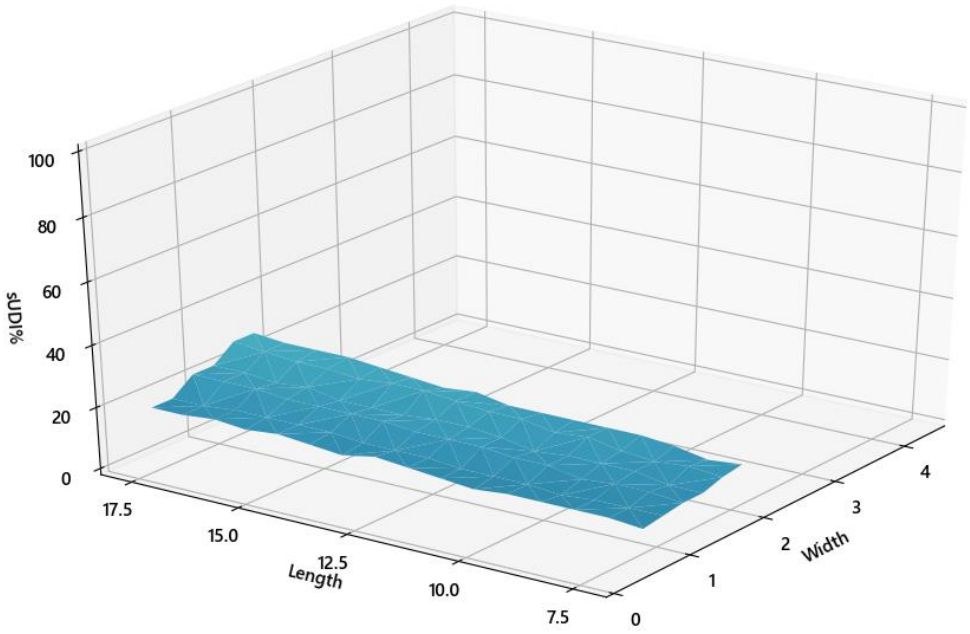
70 %

SENSITIVITY ANALYSIS

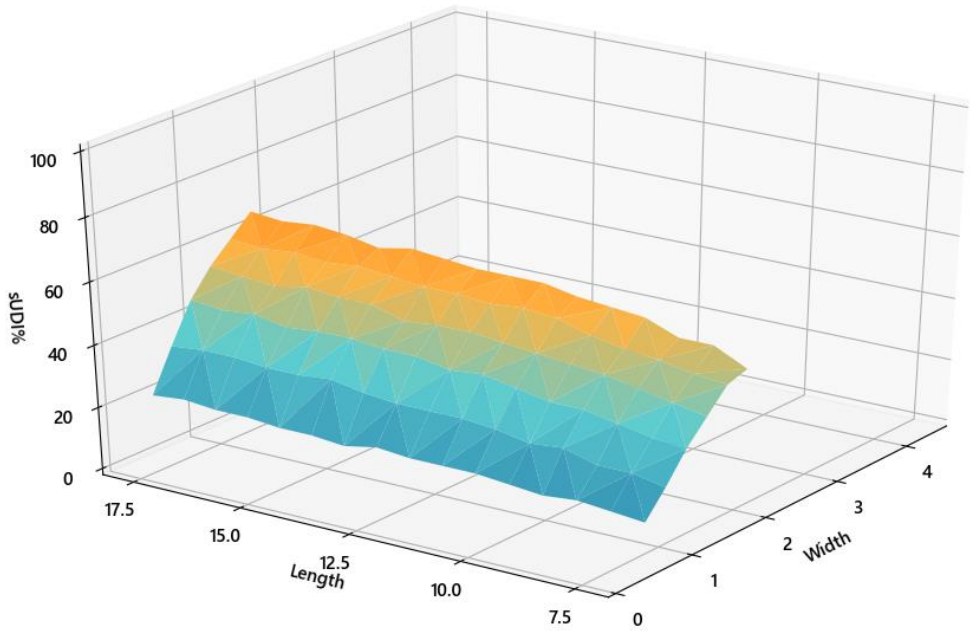
TRANSLUCENT PANEL 25%

SENSITIVITY ANALYSIS

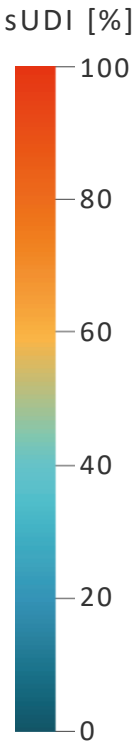
TRANSLUCENT PANEL 25%



height = 4.3 m

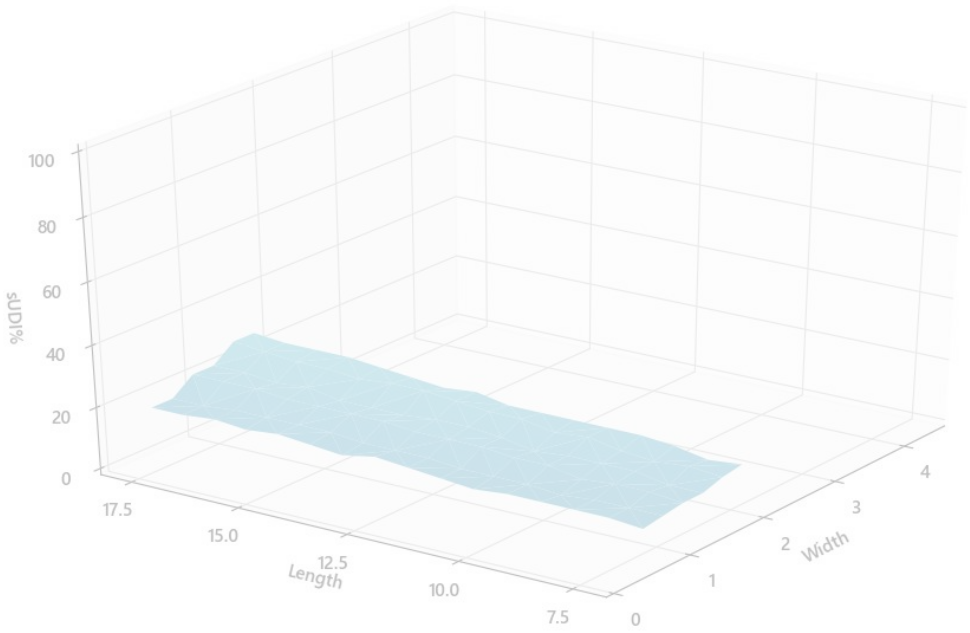


height = 1.5 m

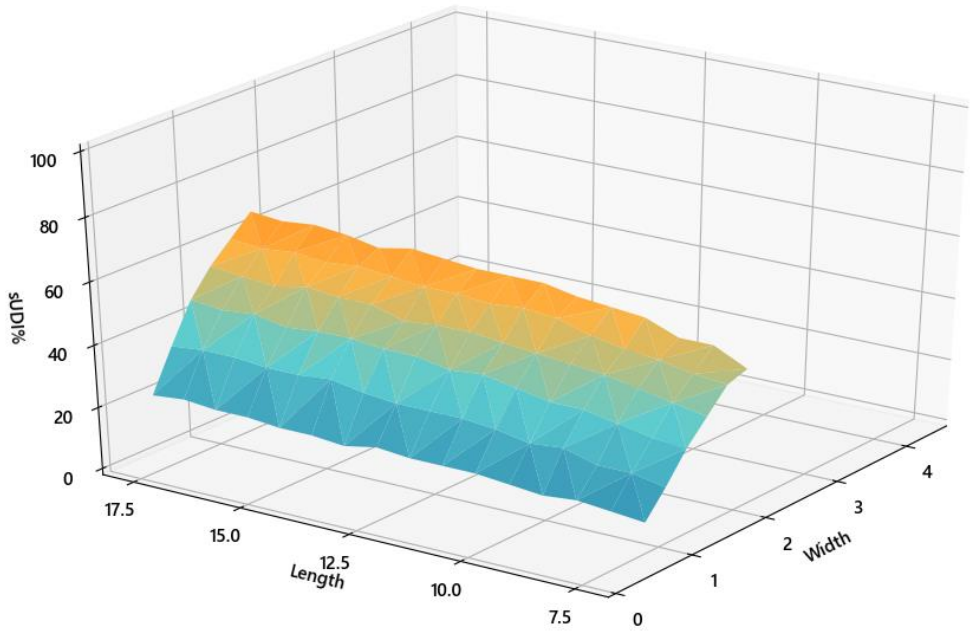


SENSITIVITY ANALYSIS

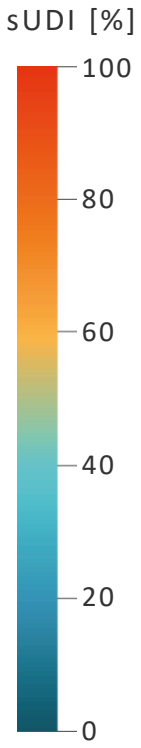
TRANSLUCENT PANEL 25%



height = 4.3 m

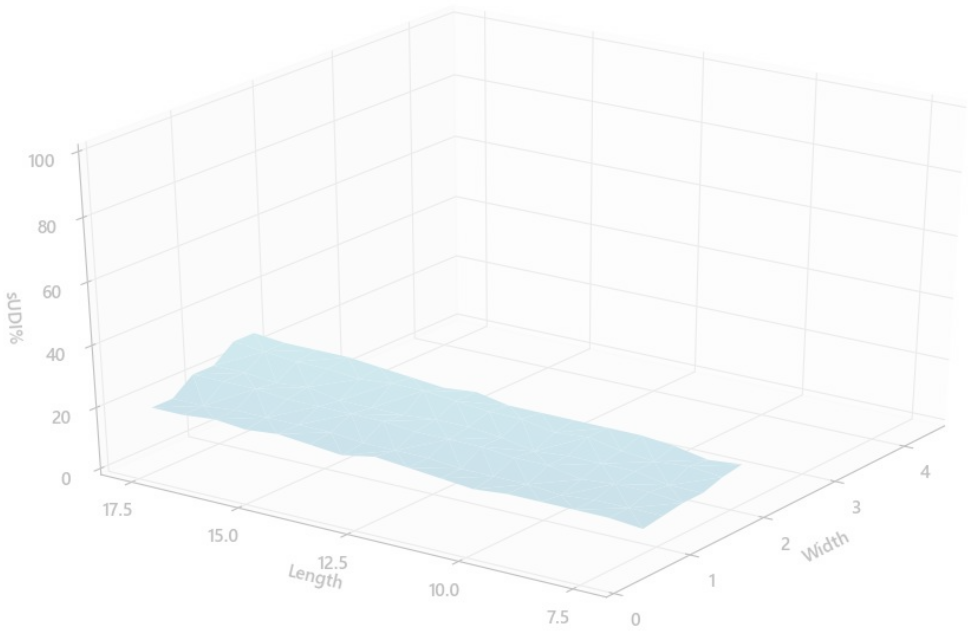


height = 1.5 m

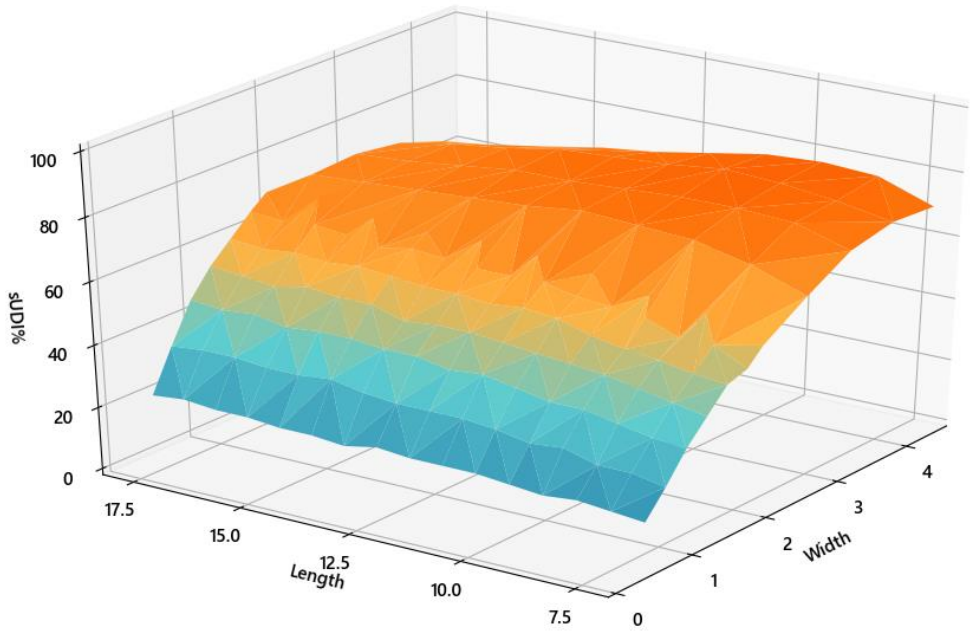


SENSITIVITY ANALYSIS

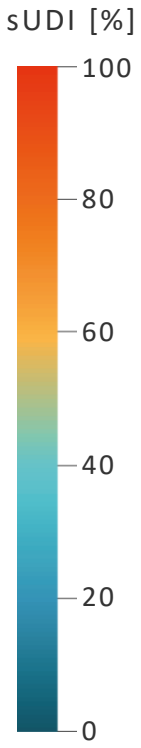
TRANSLUCENT PANEL 25%



height = 4.3 m



height = 1.5 m

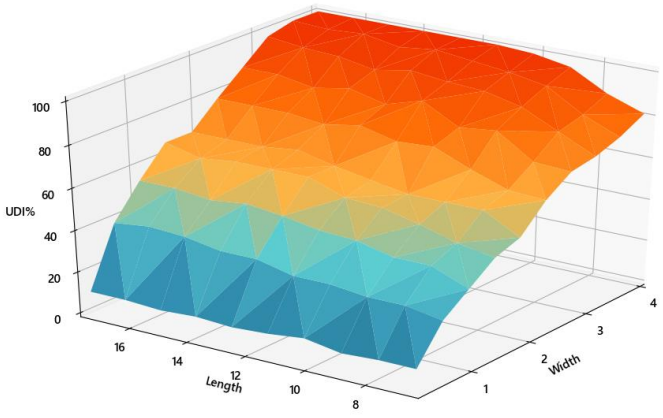


SENSITIVITY ANALYSIS

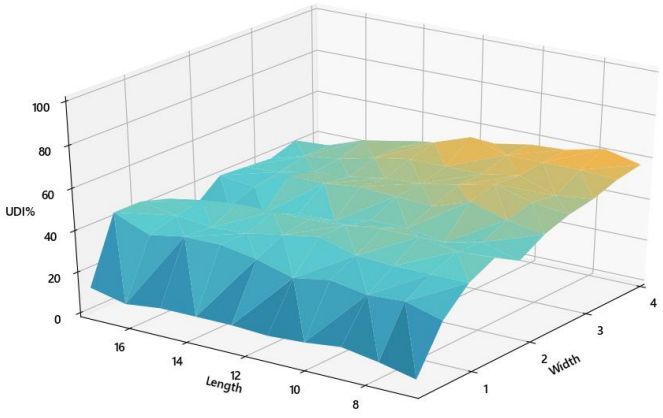
HEIGHT = 1.5 M

SENSITIVITY ANALYSIS

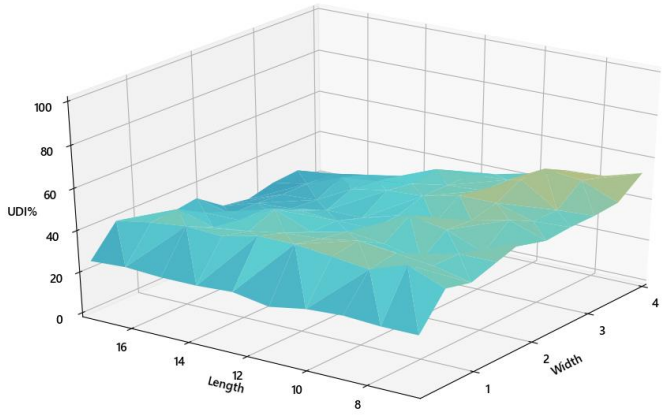
HEIGHT = 1.5 M



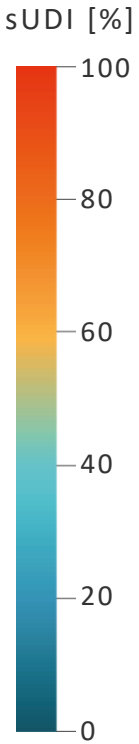
translucent panel 15%



translucent panel 45%

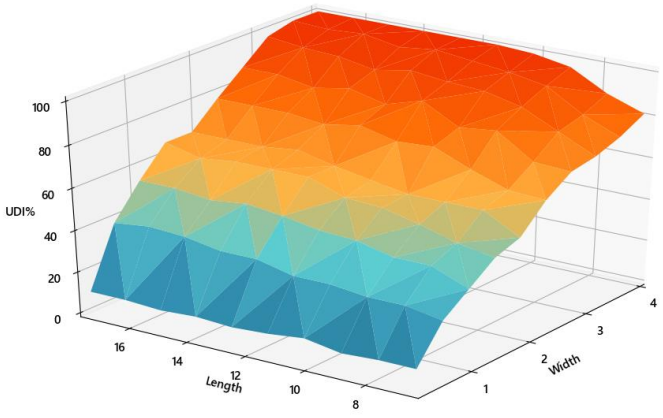


translucent panel 65%

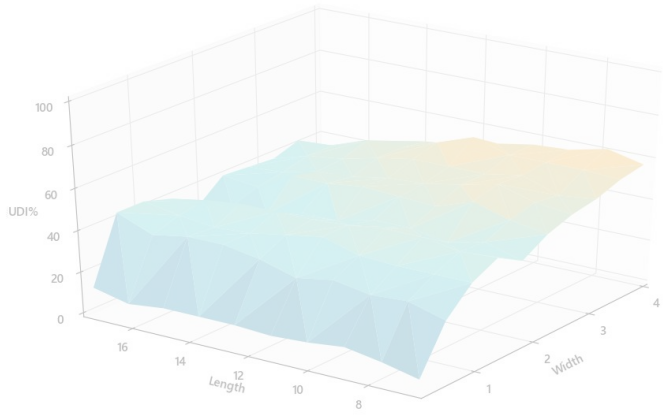


SENSITIVITY ANALYSIS

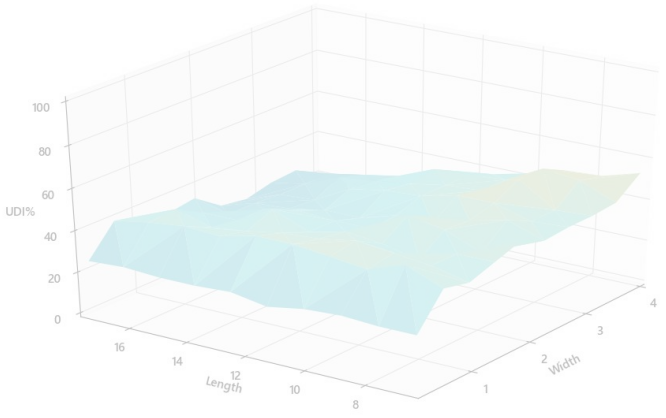
HEIGHT = 1.5 M



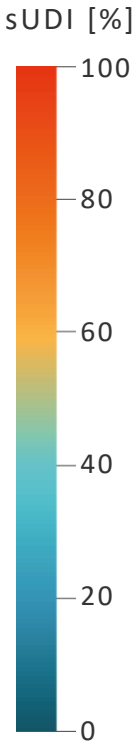
translucent panel 15%



translucent panel 45%

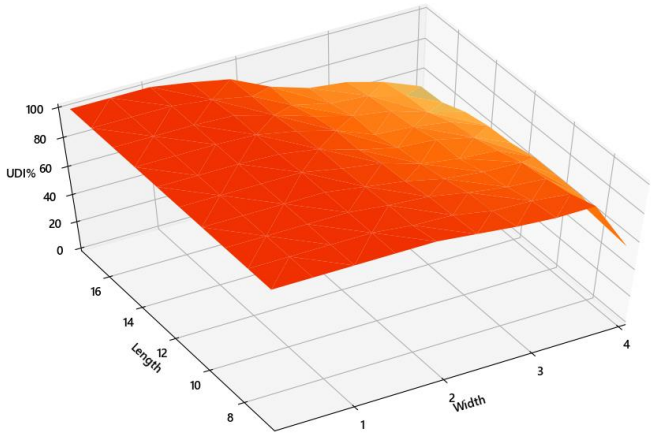


translucent panel 65%



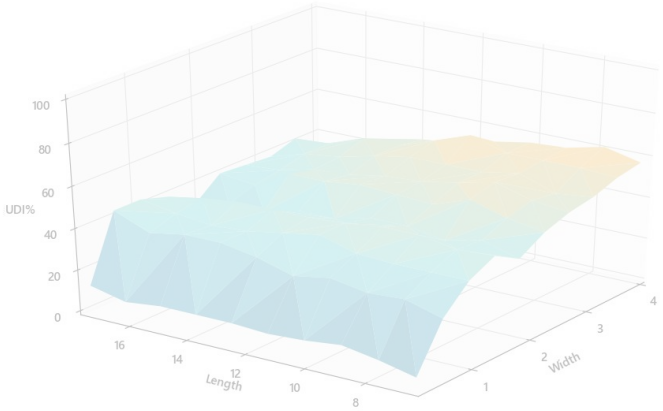
SENSITIVITY ANALYSIS

HEIGHT = 1.5 M

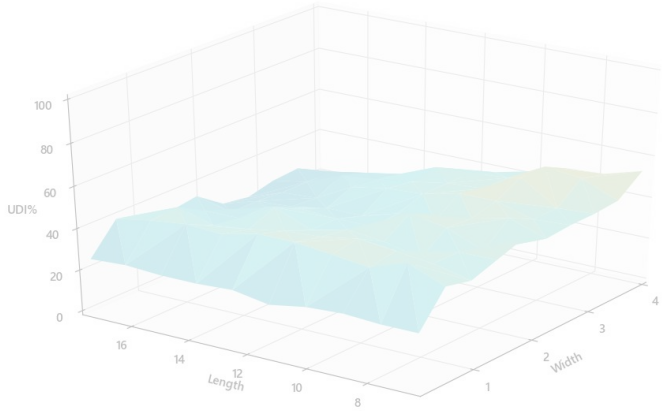


translucent panel 15%

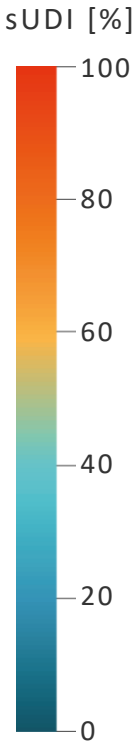
sUDI [-1 lux , 55 lux]



translucent panel 45%



translucent panel 65%



SENSITIVITY ANALYSIS

RESULTS DISCUSSION

SENSITIVITY ANALYSIS

RESULTS DISCUSSION

IMPROVE DAYLIGHT CONDITIONS

SENSITIVITY ANALYSIS

RESULTS DISCUSSION

IMPROVE DAYLIGHT CONDITIONS

height = 1.5 m

higher area

translucent panel 25%

SENSITIVITY ANALYSIS

RESULTS DISCUSSION

IMPROVE DAYLIGHT CONDITIONS

height = 1.5 m

higher area

translucent panel 25%

CONSTRAINTS FOR THE MULTI-OBJECTIVE WORKFLOW

SENSITIVITY ANALYSIS

RESULTS DISCUSSION

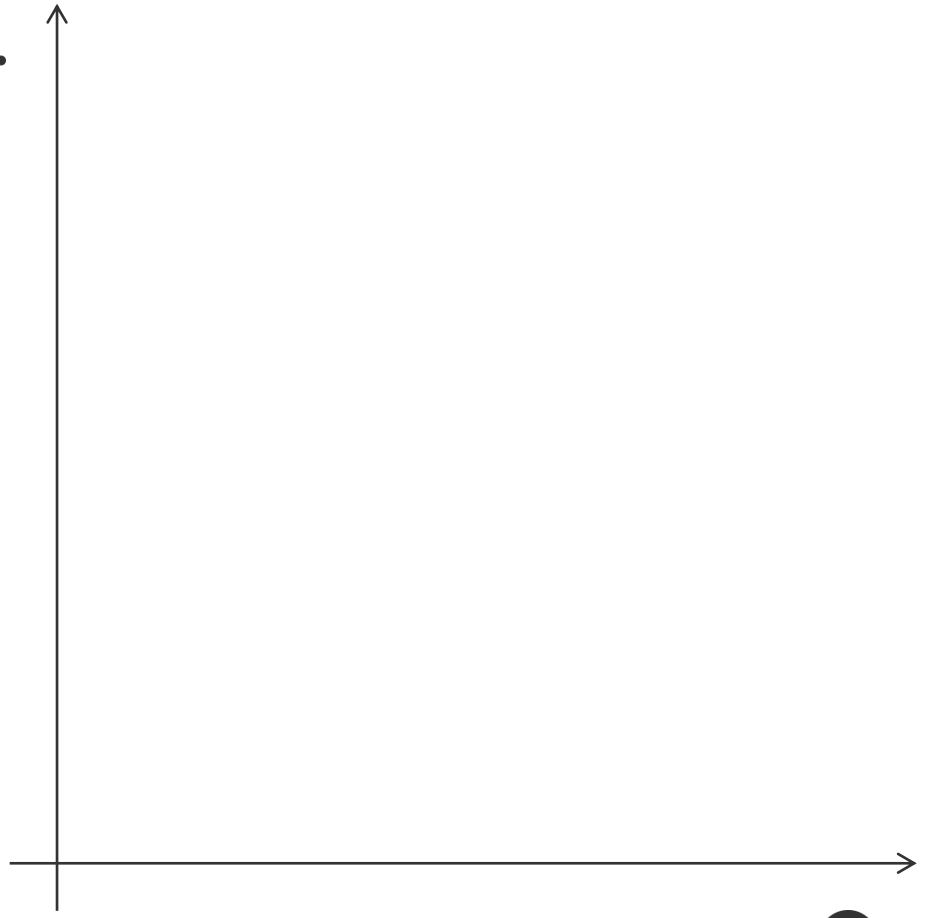
IMPROVE DAYLIGHT CONDITIONS	CONSTRAINTS FOR THE MULTI-OBJECTIVE WORKFLOW
height = 1.5 m	fix height at 1.5 m
higher area	length [6.5 m , 17.5 m]
translucent panel 25%	width [1.5 m , 4.0 m]
	translucent panels 25%, 35%, 45%

MULTI-OBJECTIVE OPTIMIZATION

OBJECTIVES

OBJECTIVES

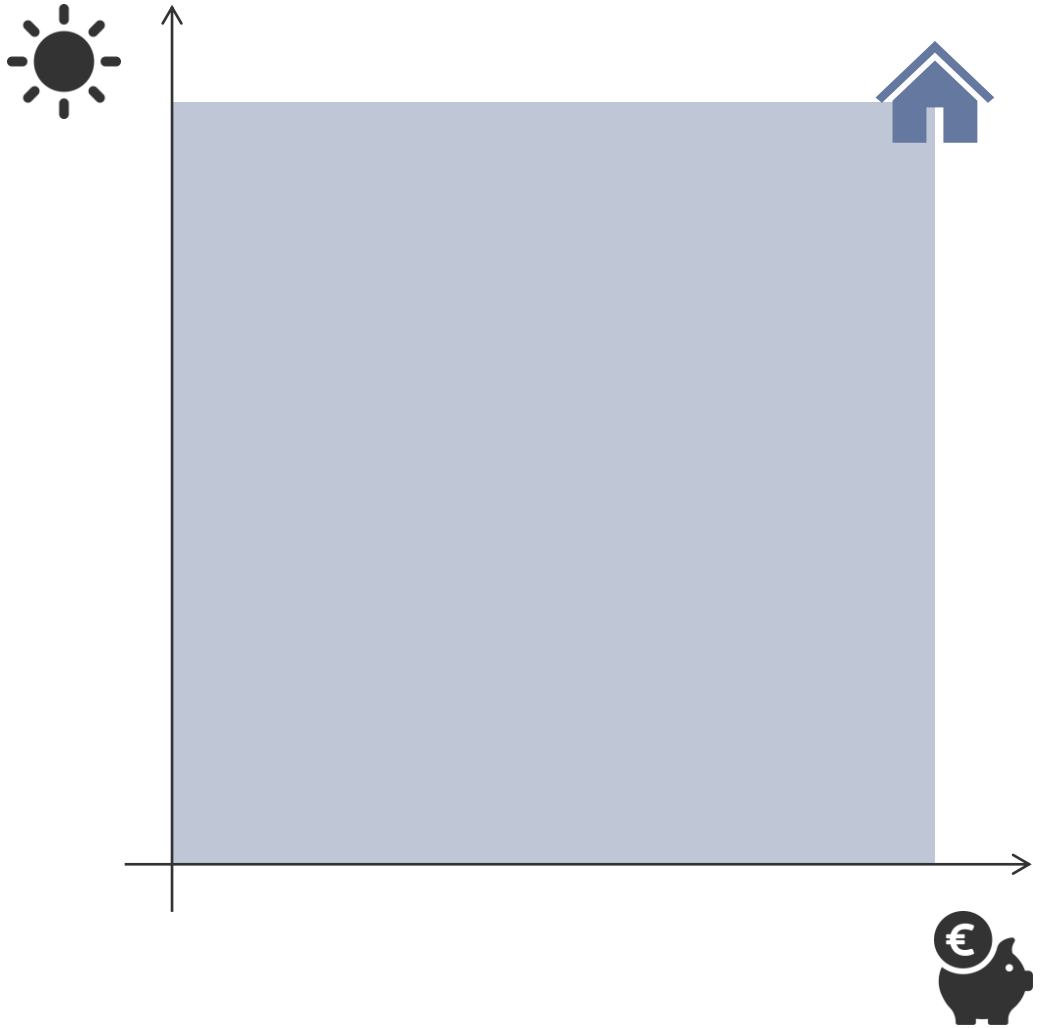
OBJECTIVES



OBJECTIVES

OBJECTIVES

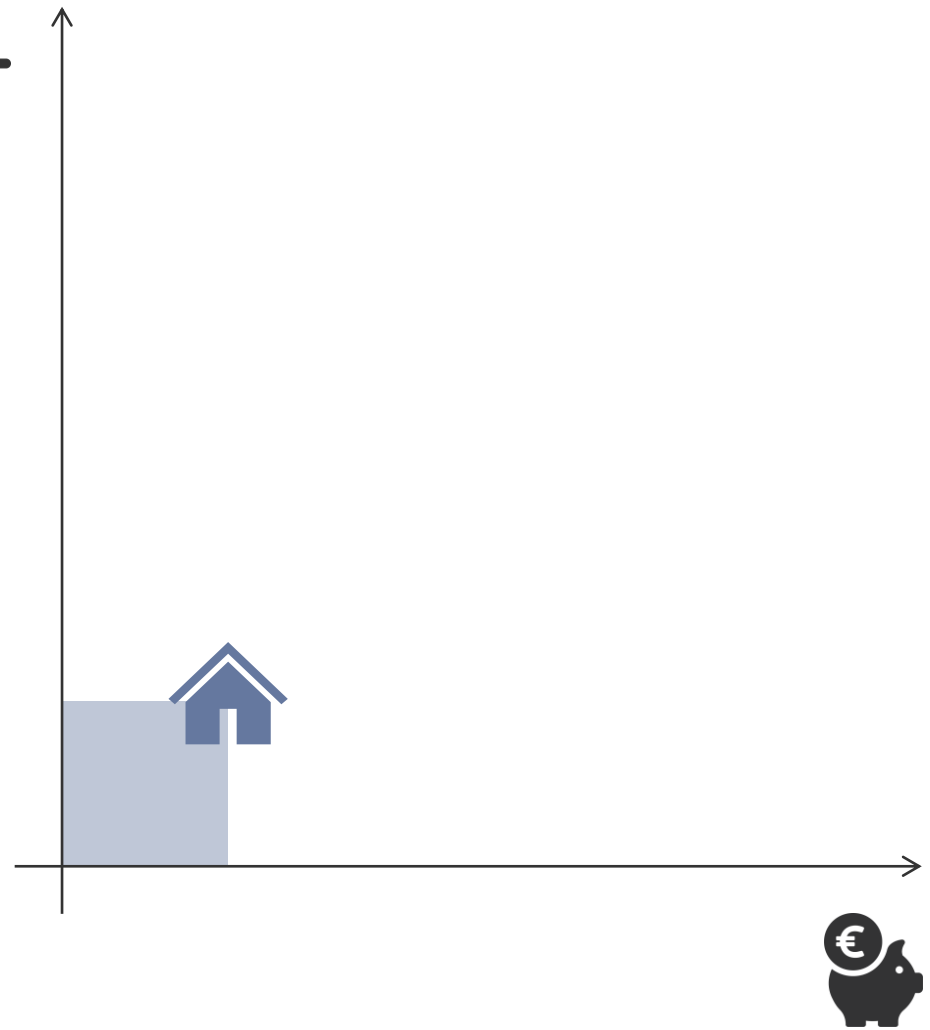
maximize



OBJECTIVES

OBJECTIVES

minimize

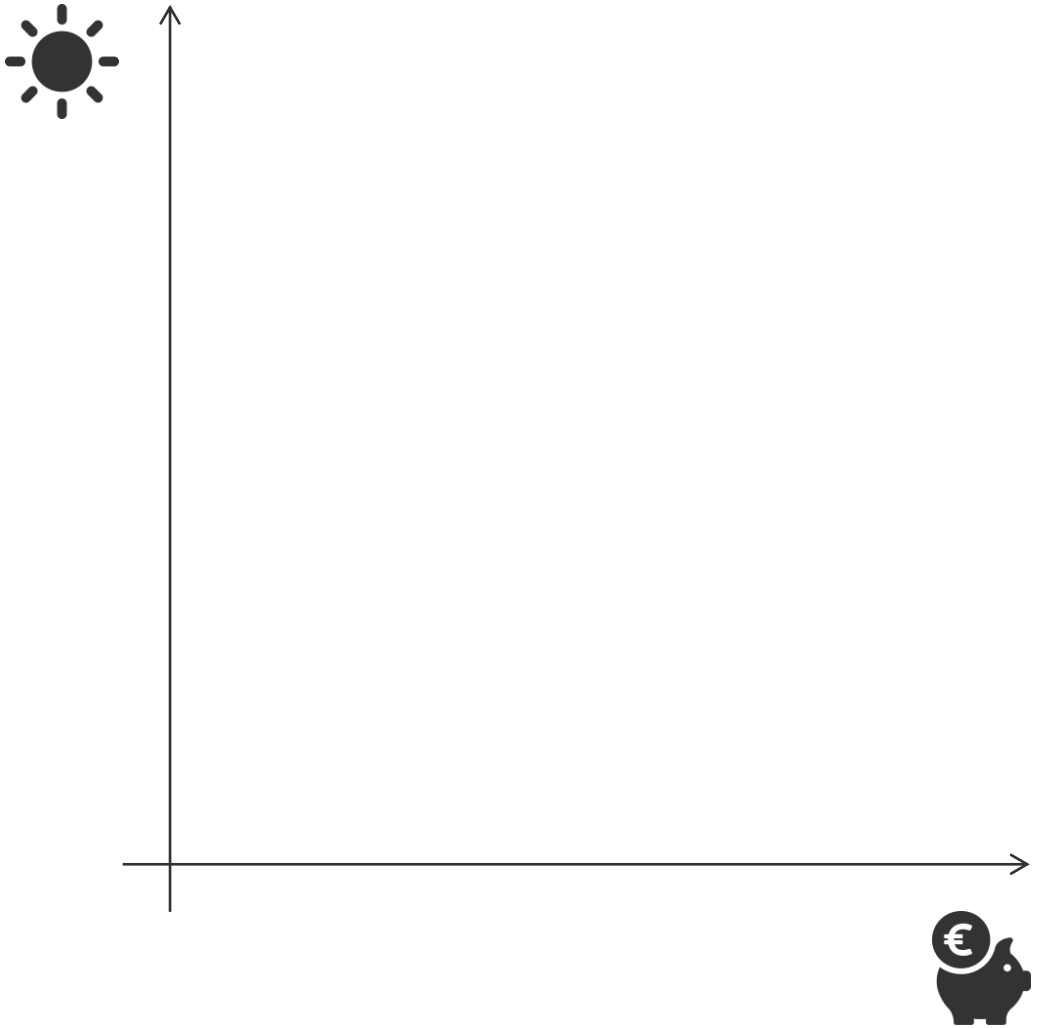


OBJECTIVES

OBJECTIVES

maximize

minimize

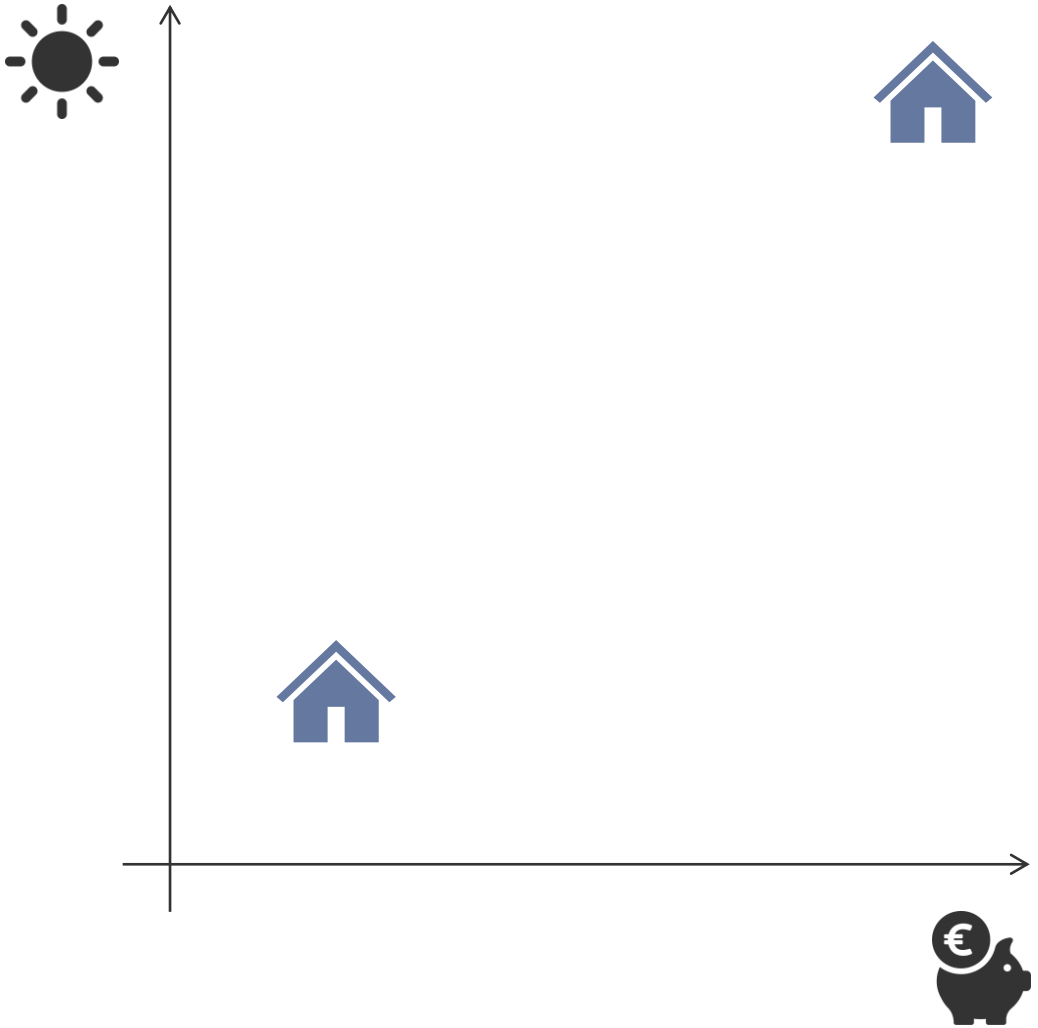


OBJECTIVES

OBJECTIVES

maximize

minimize

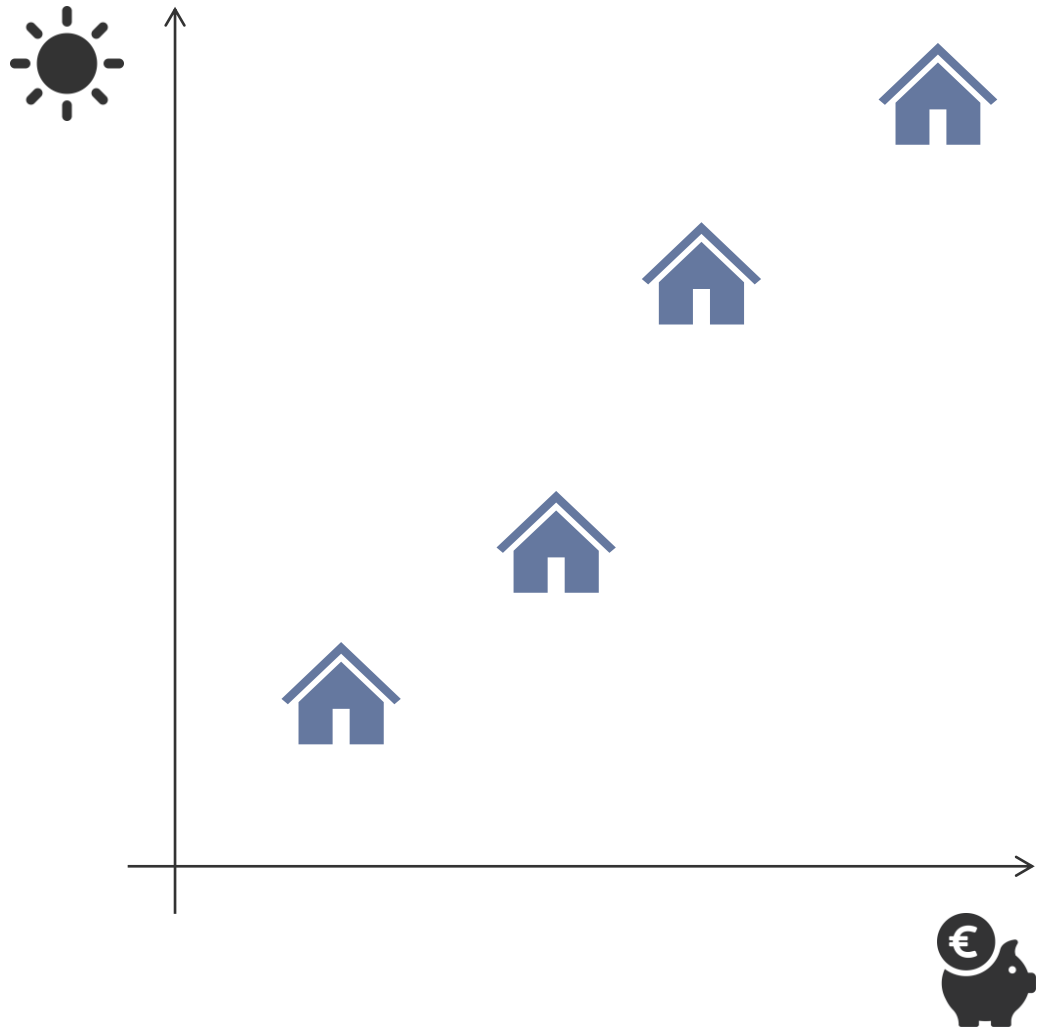


OBJECTIVES

OBJECTIVES

maximize

minimize

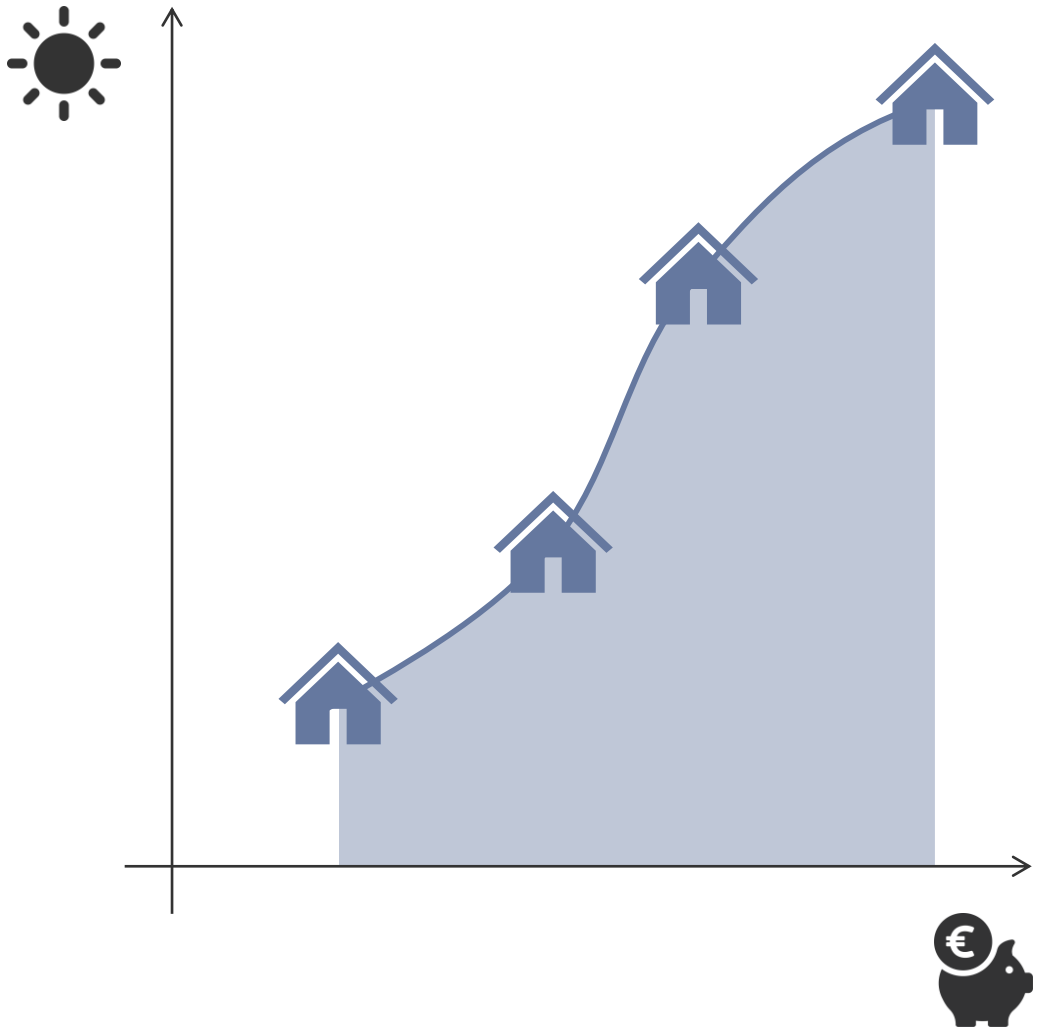


OBJECTIVES

OBJECTIVES

maximize

minimize



OPTIMIZATION ALGORITHM

GENETIC ALGORITHM

OPTIMIZATION ALGORITHM

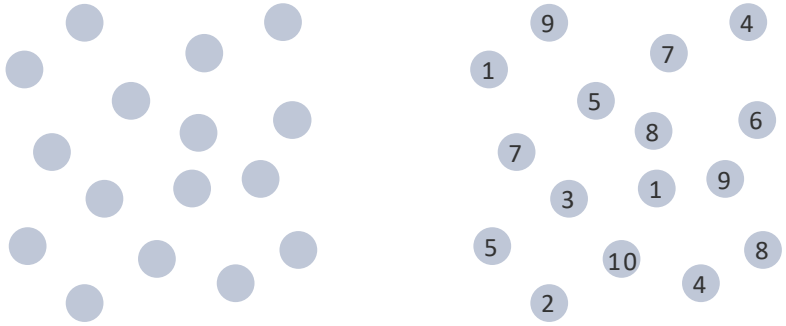
GENETIC ALGORITHM

create
population

OPTIMIZATION ALGORITHM

GENETIC ALGORITHM

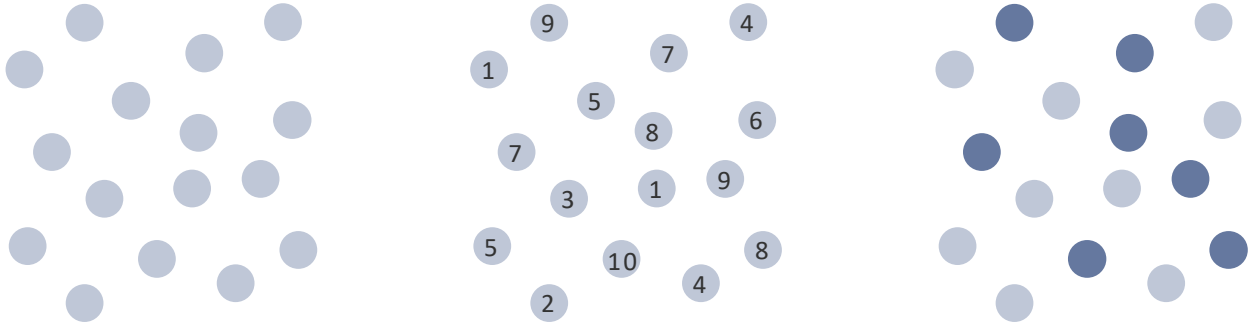
create population → evaluate population



OPTIMIZATION ALGORITHM

GENETIC ALGORITHM

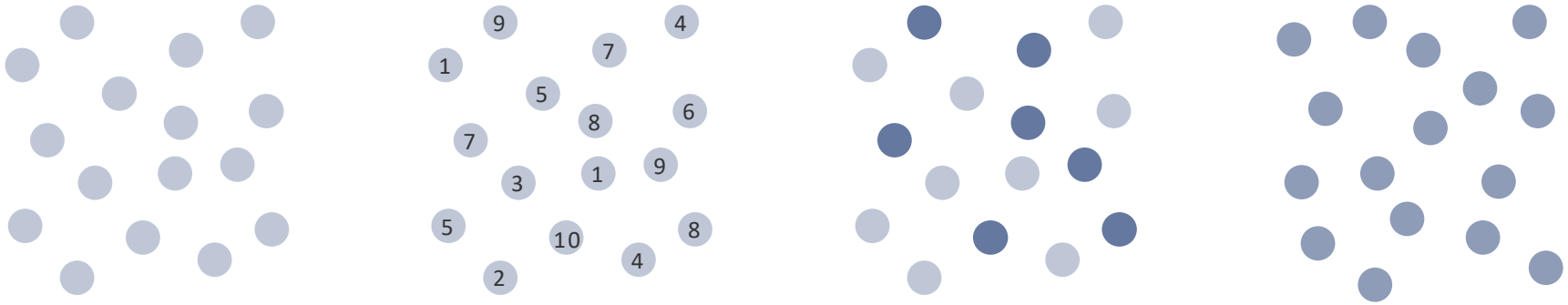
create population → evaluate population → select parents



OPTIMIZATION ALGORITHM

GENETIC ALGORITHM

create population → evaluate population → select parents → create children



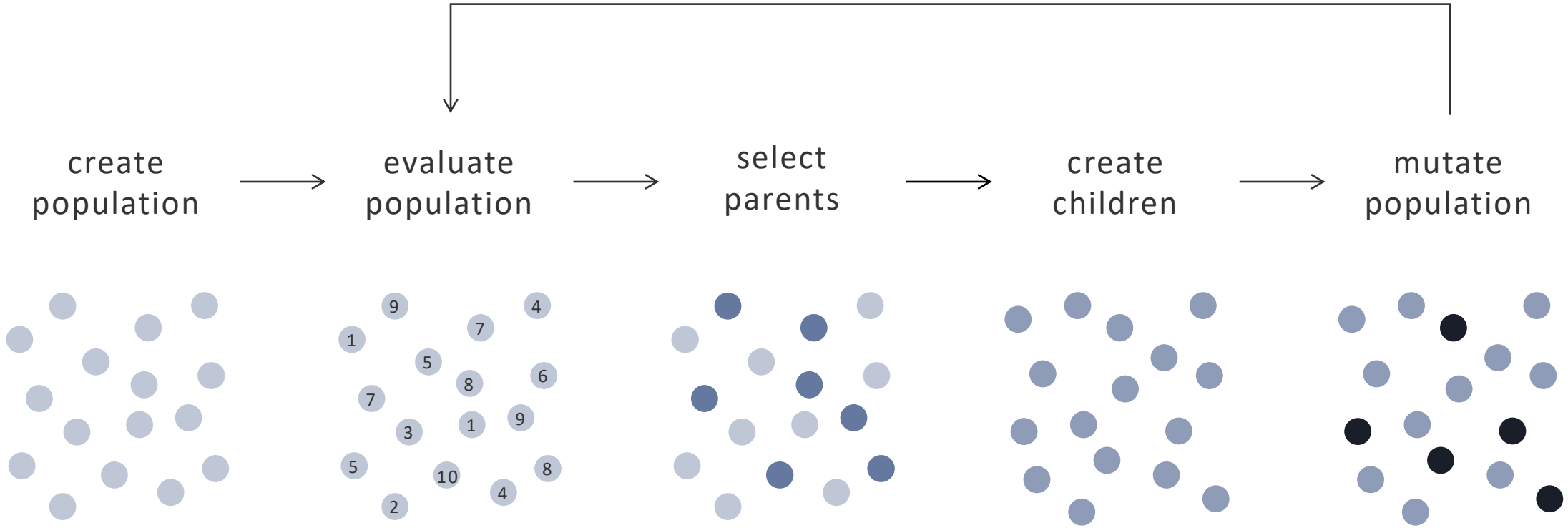
OPTIMIZATION ALGORITHM

GENETIC ALGORITHM

create population → evaluate population → select parents → create children → mutate population

OPTIMIZATION ALGORITHM

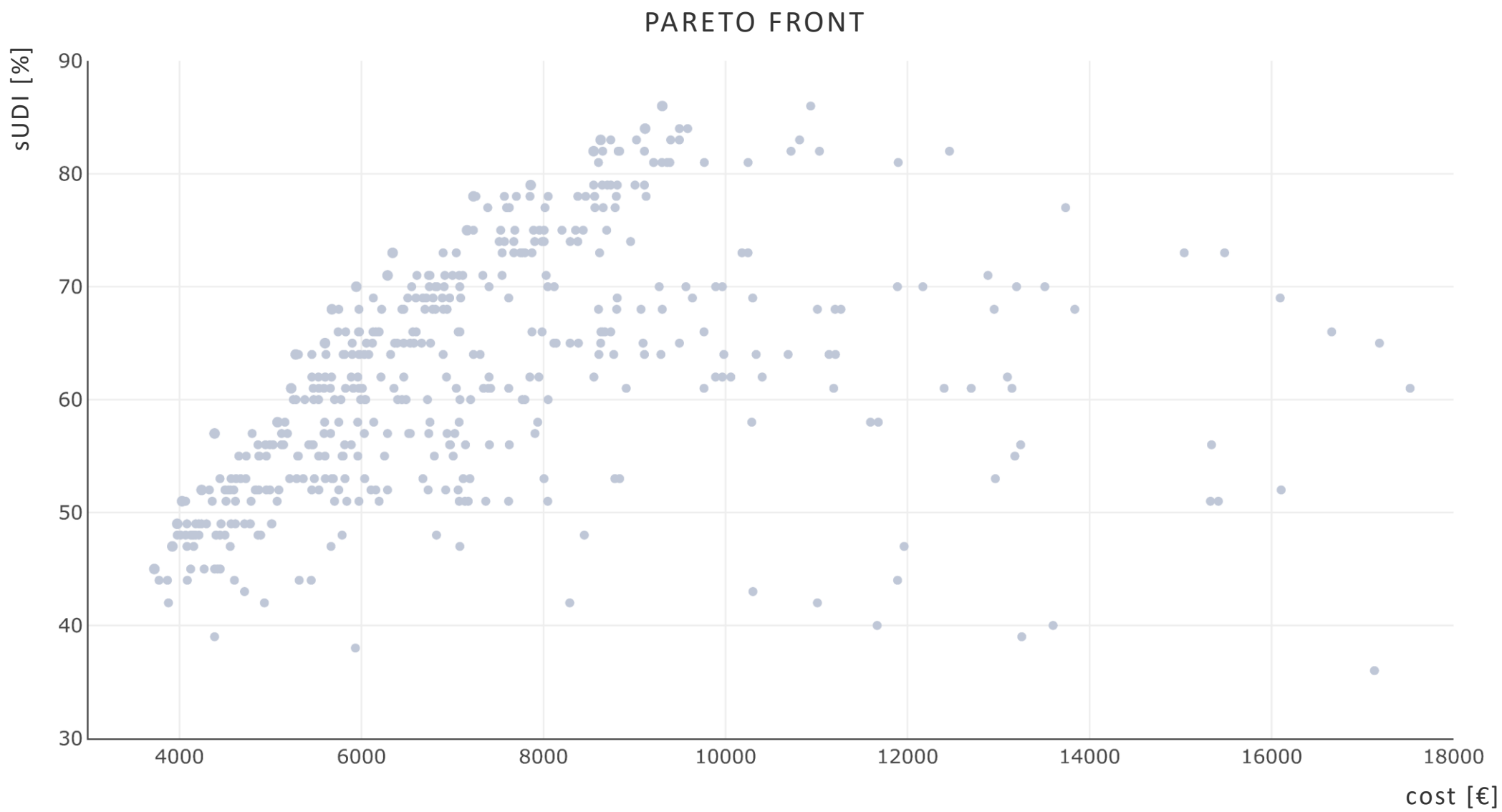
GENETIC ALGORITHM



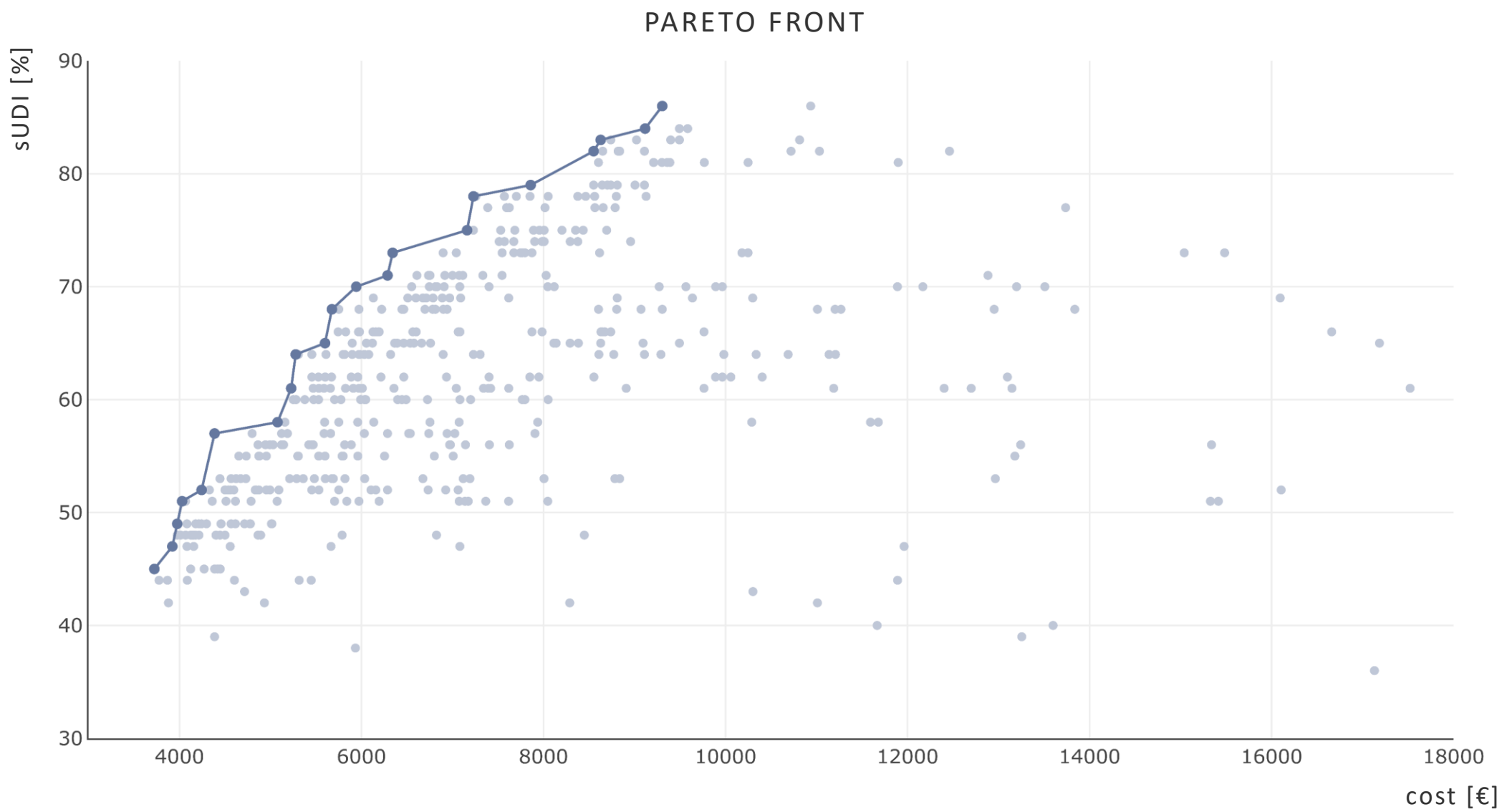
VISUALIZATION

PARETO FRONT

VISUALIZATION

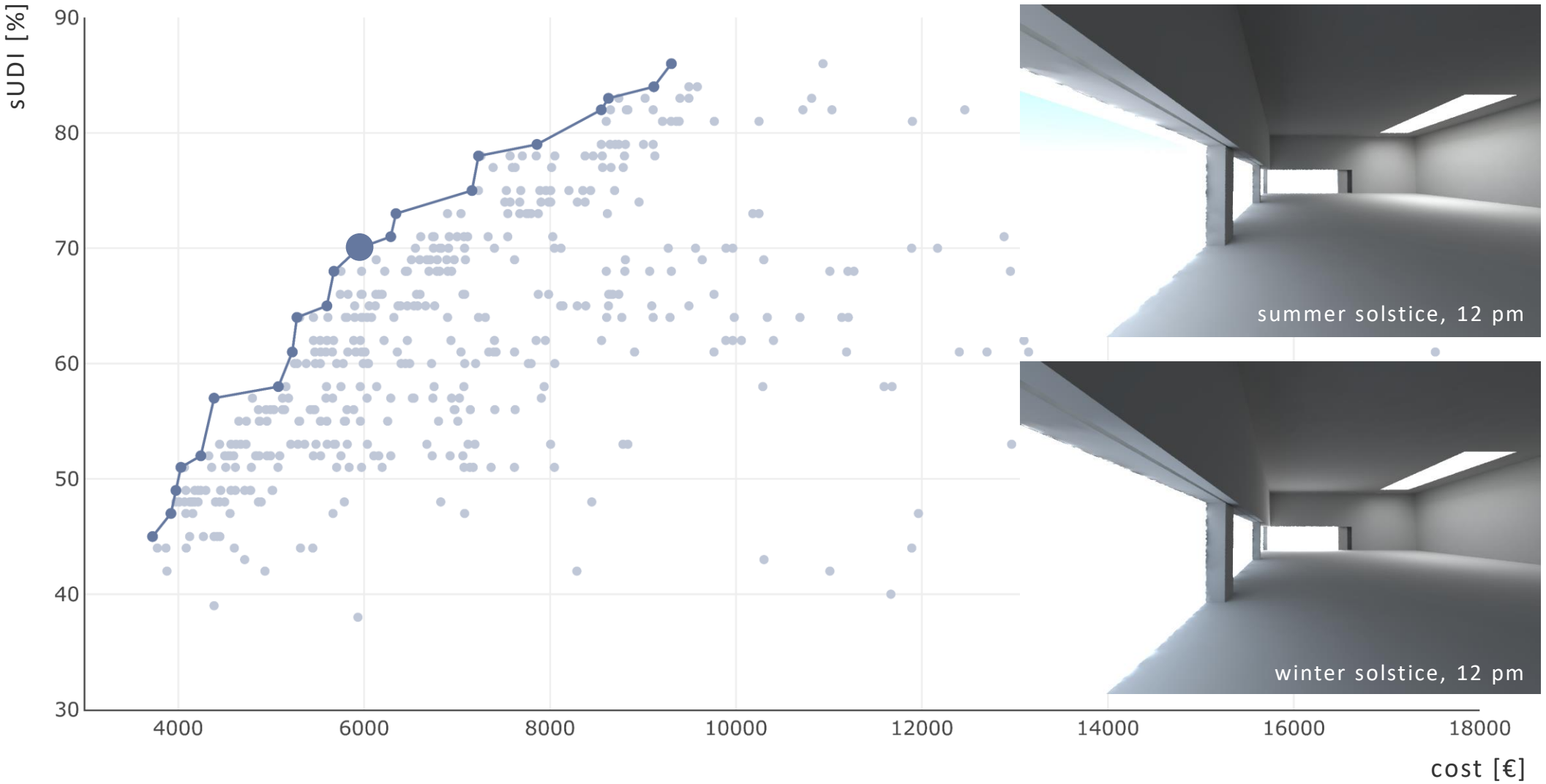


VISUALIZATION



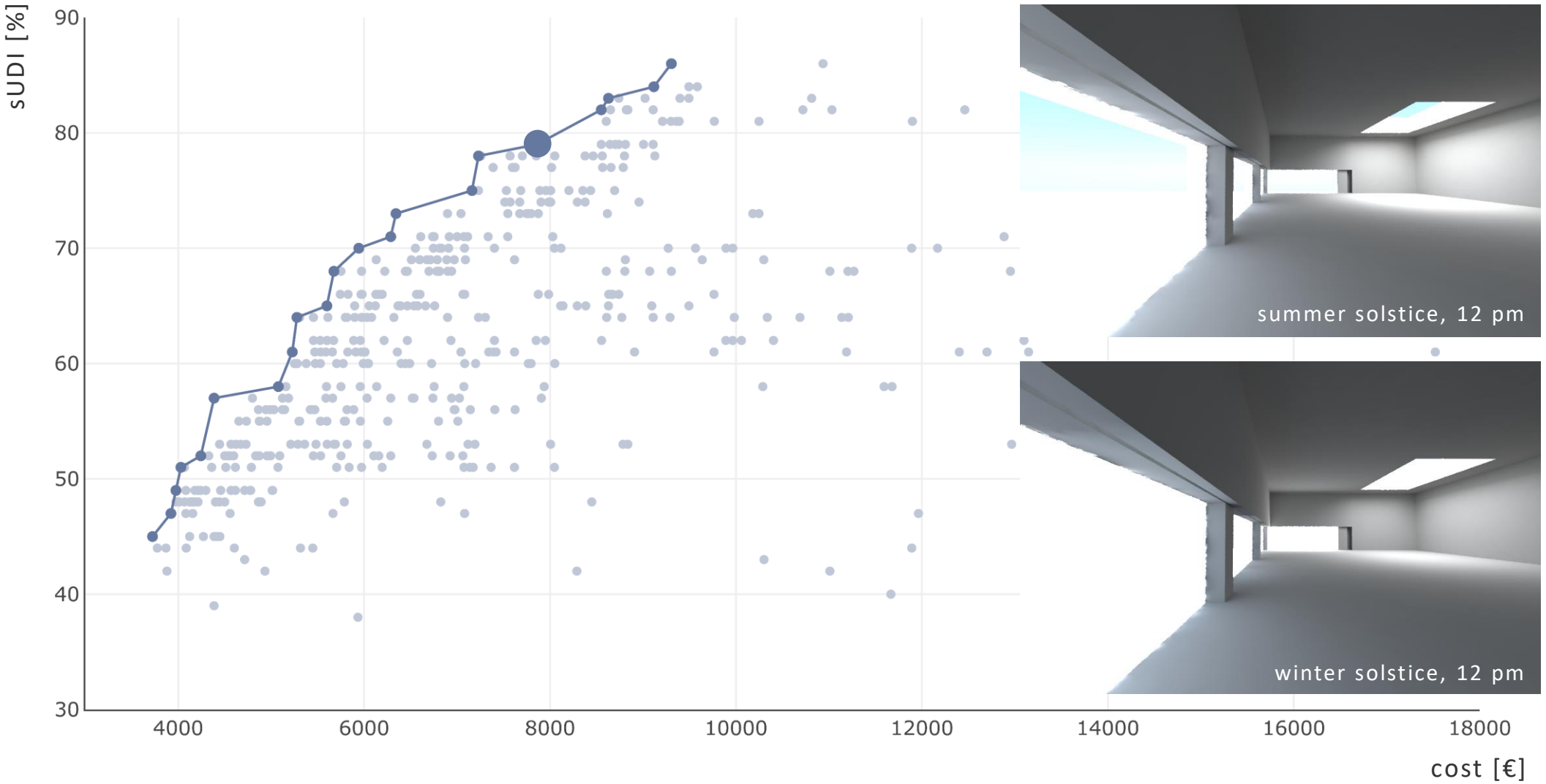
VISUALIZATION

PARETO FRONT



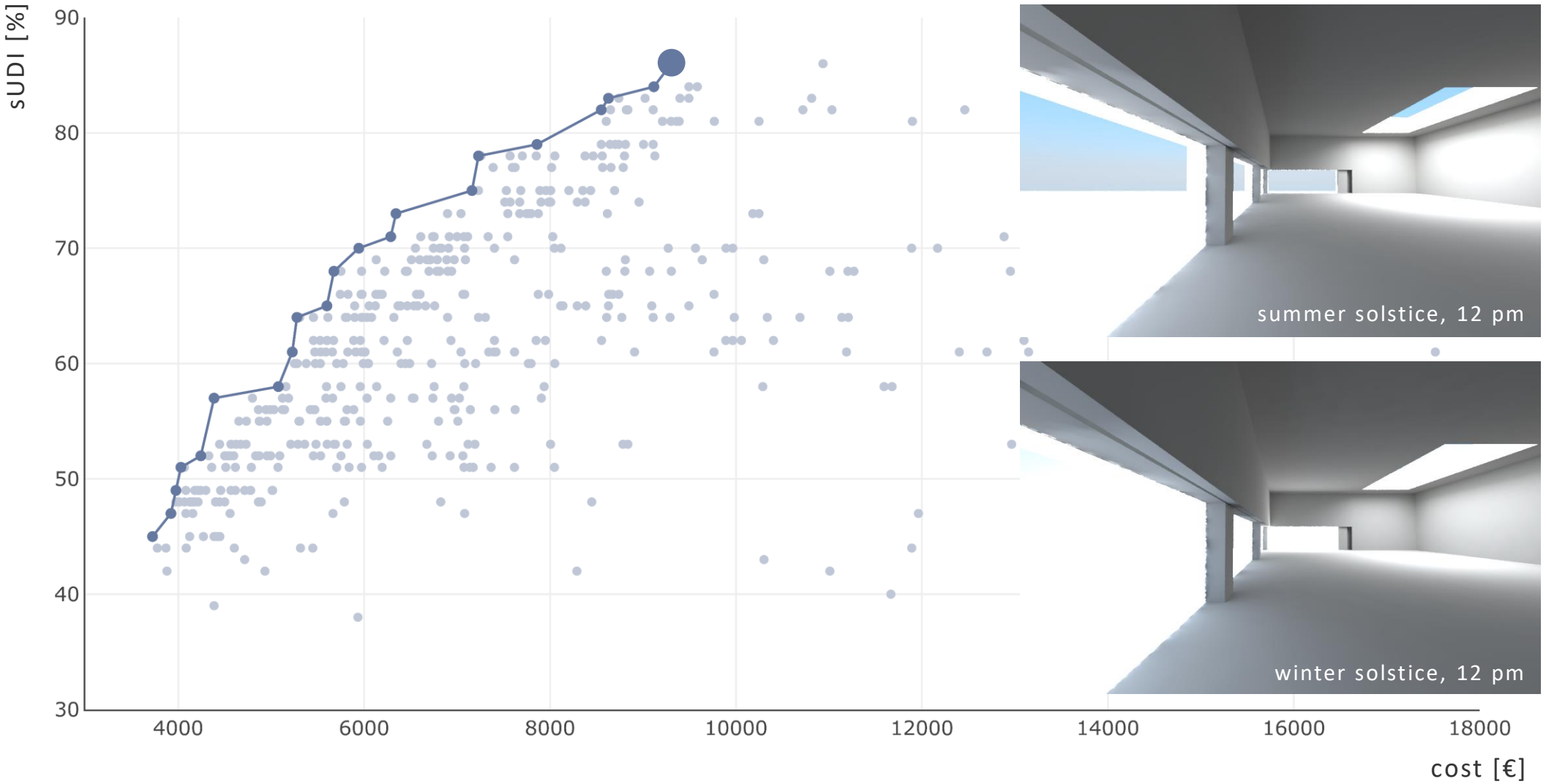
VISUALIZATION

PARETO FRONT

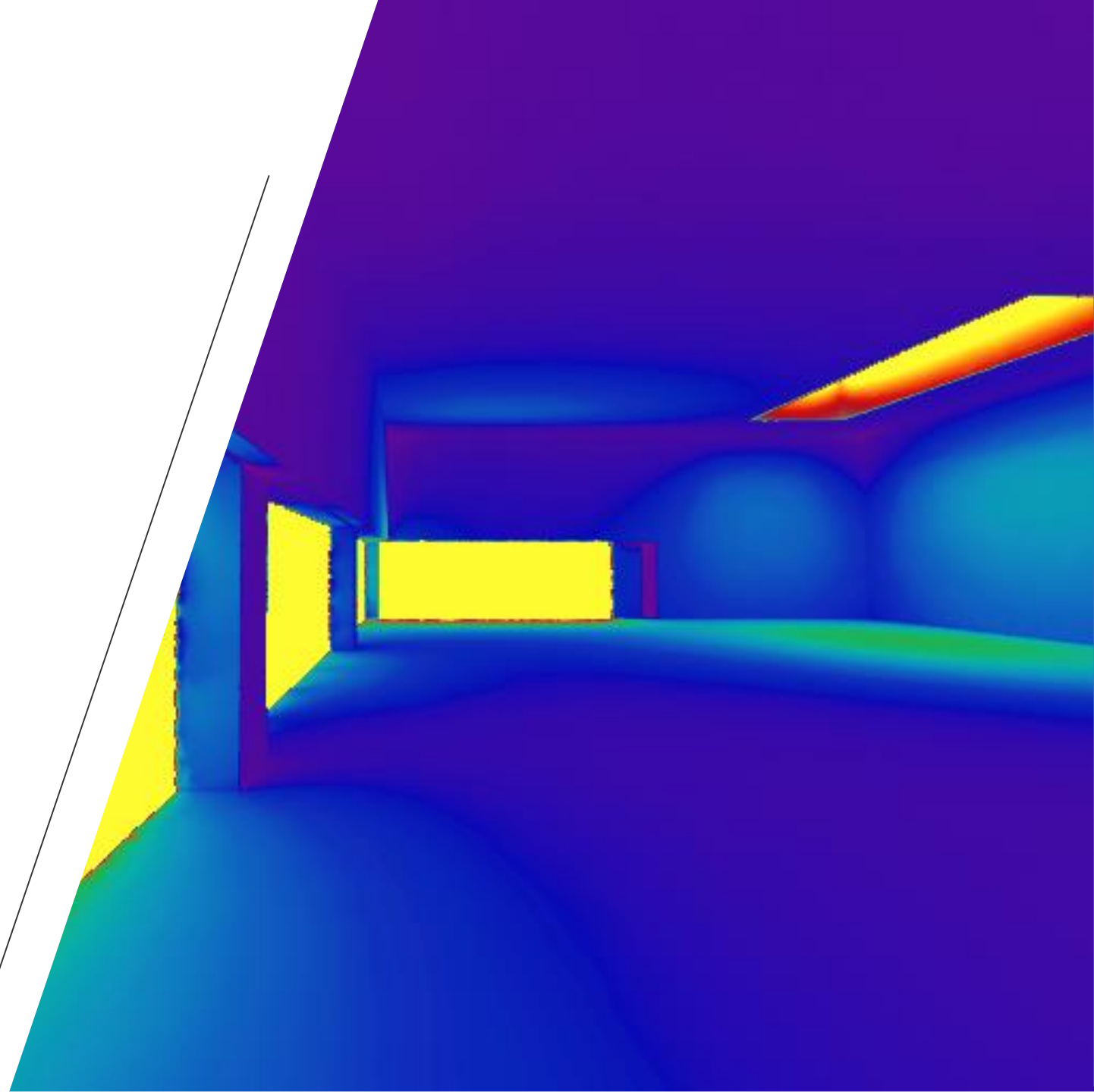


VISUALIZATION

PARETO FRONT



CONCLUSION



CONCLUSION

importance of
evaluate performance

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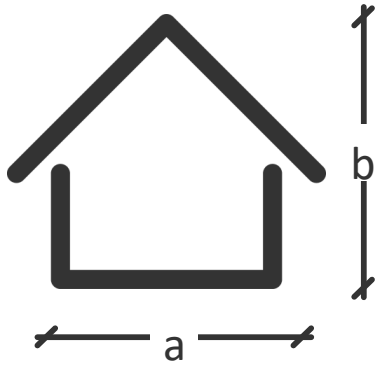
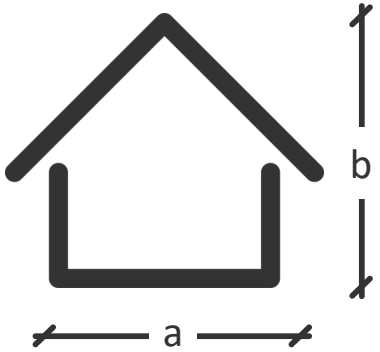


relevance of
parametric models

CONCLUSION

importance of
evaluate performance



relevance of
parametric models

small scale buildings
also benefit from AD

FUTURE WORK

FUTURE WORK

test different
optimization algorithms

FUTURE WORK

test different
optimization algorithms

add more
objectives

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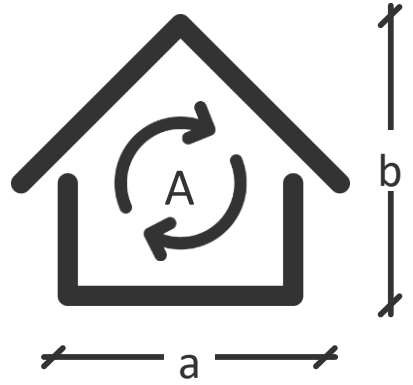
test different
optimization algorithms

add more
objectives



automate the creation of
parametric models

CONTRIBUTIONS

Optimizing Exhibition Spaces

A Multi-Objective Approach

Pereira, I., Belém, C. and Leitão, A.

(2019)

Proceedings of the 37th eCAADe Conference

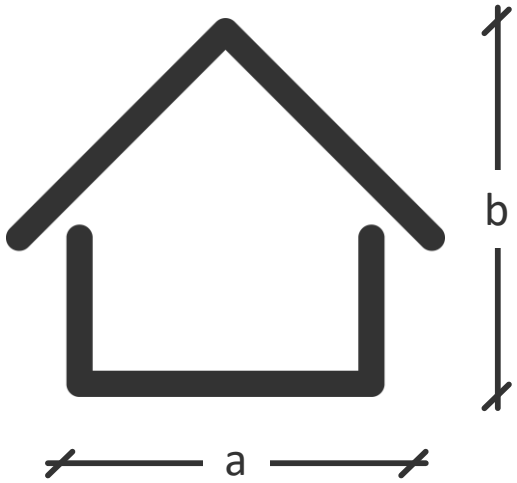
Porto University, Portugal

THANK YOU

QUESTIONS?

DESIGN SPACE

DESIGN SPACE



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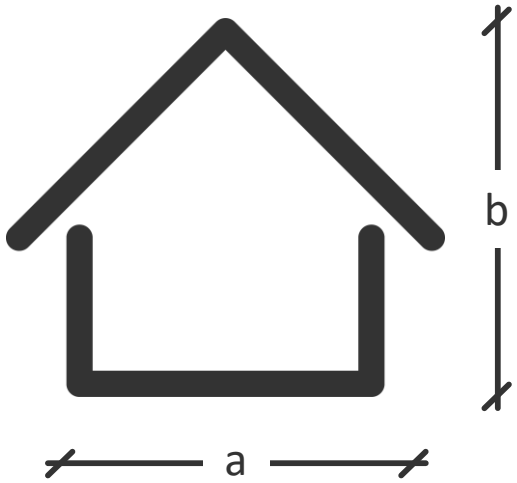

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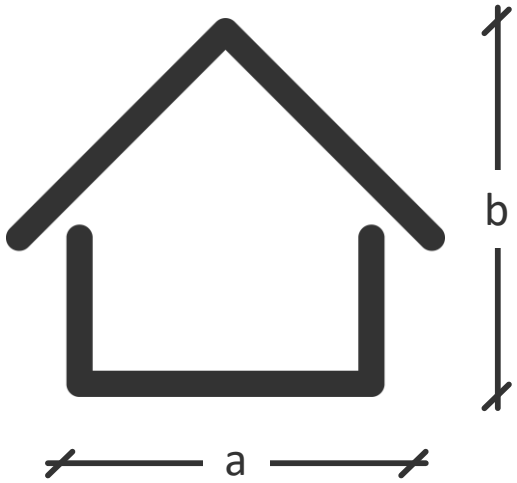
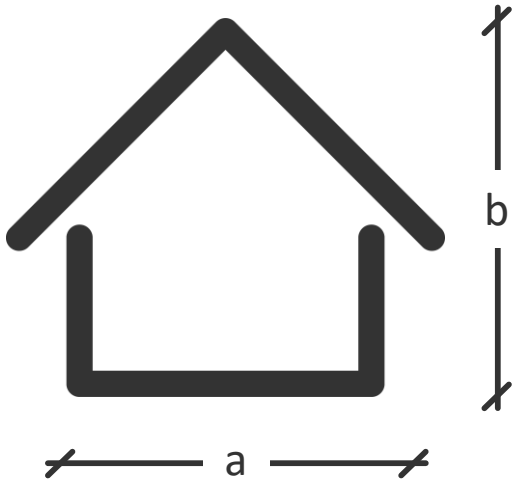


CONSTRAINTS

a $[a_1 , a_2]$

b $[b_1 , b_2]$

DESIGN SPACE



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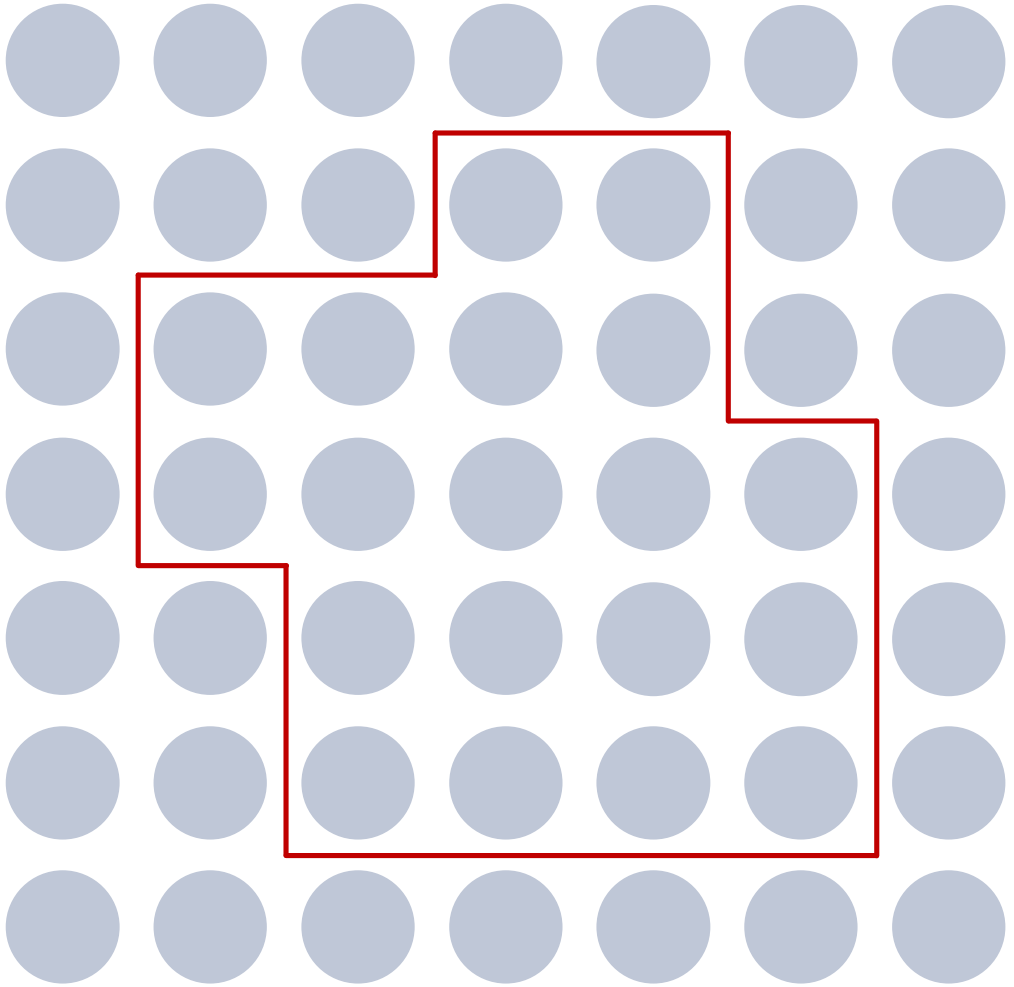

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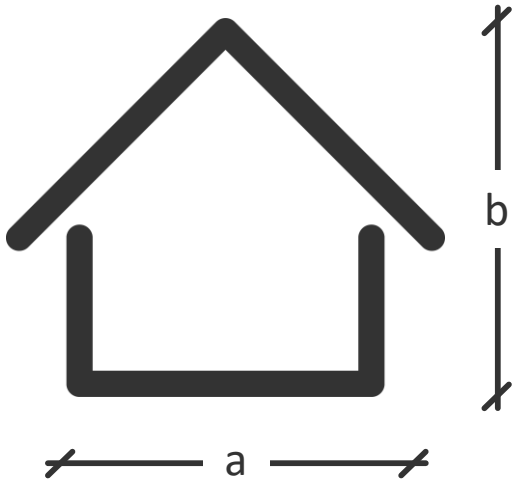

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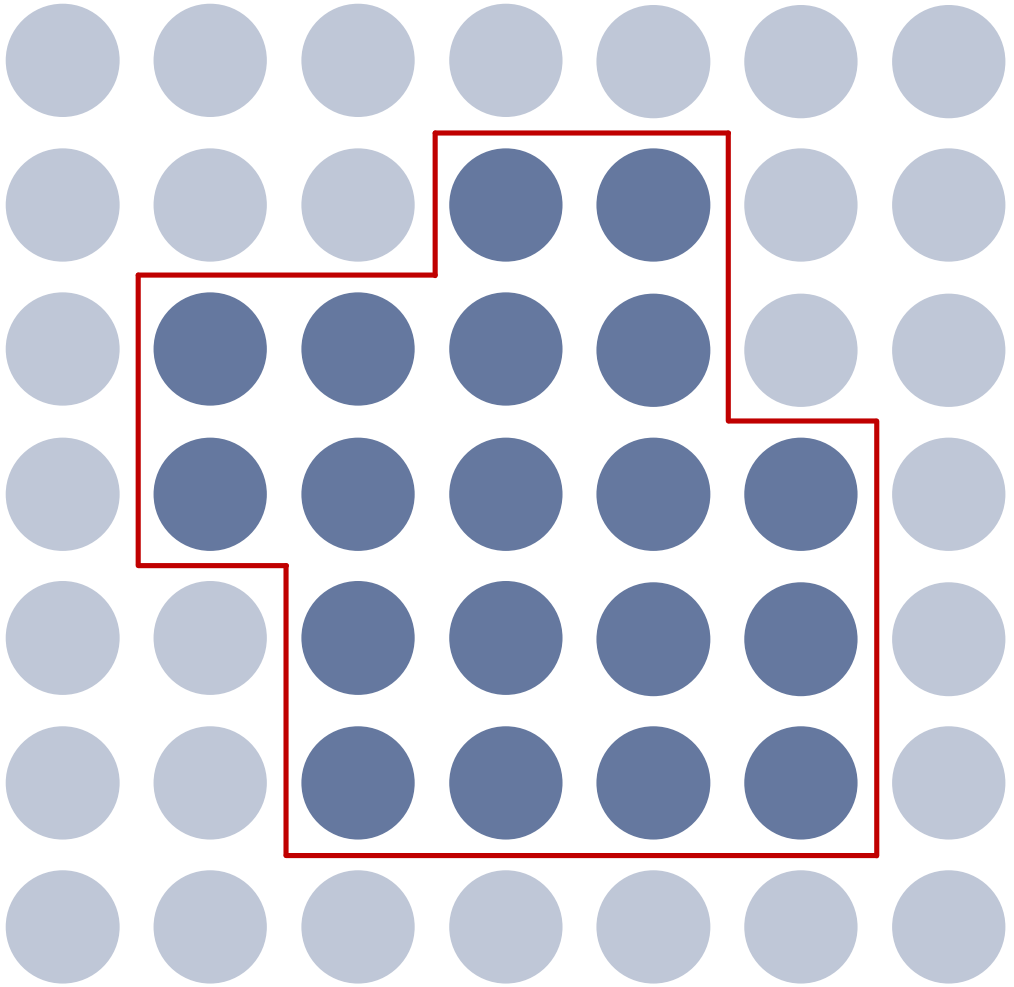

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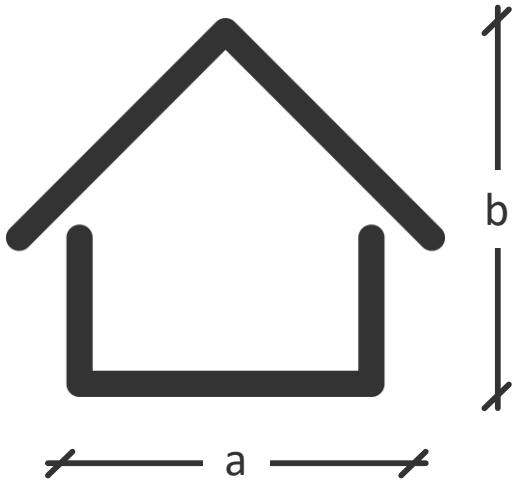

CONSTRAINTS

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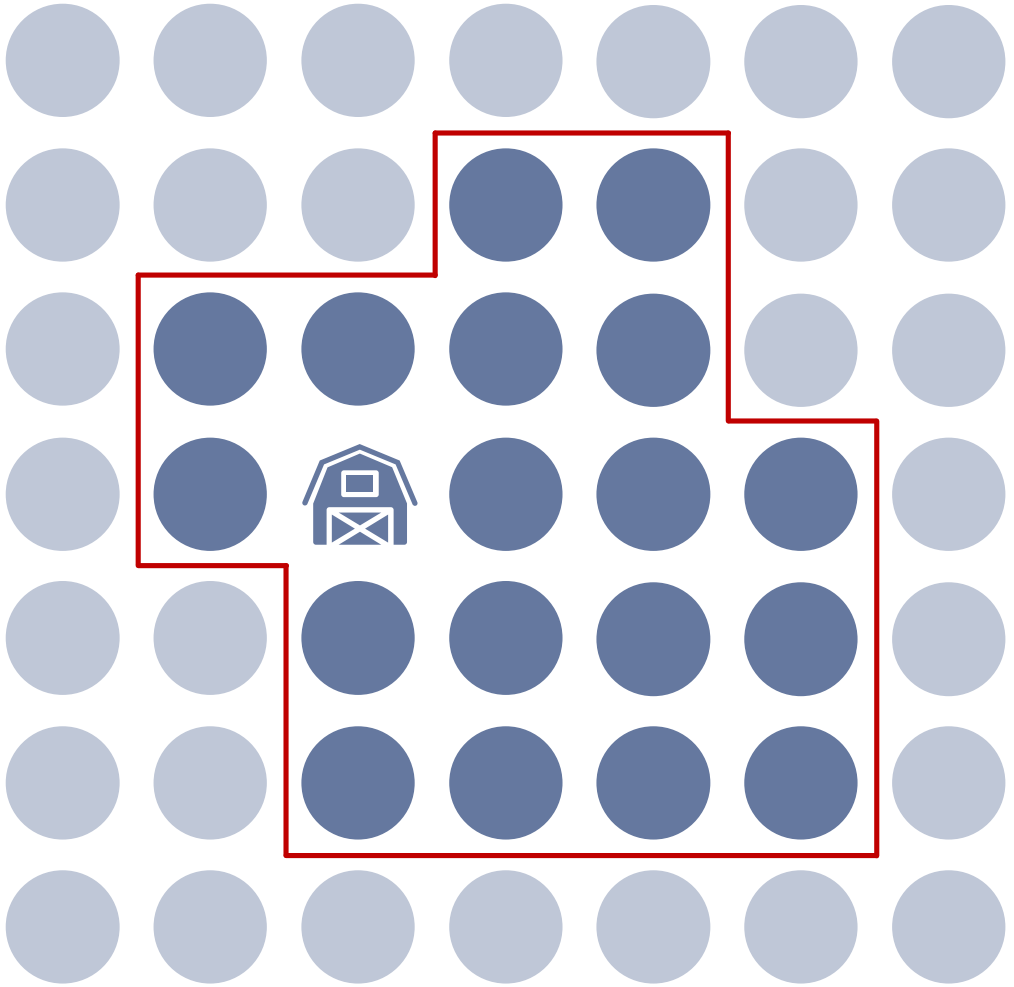
b $[b_1 , b_2]$



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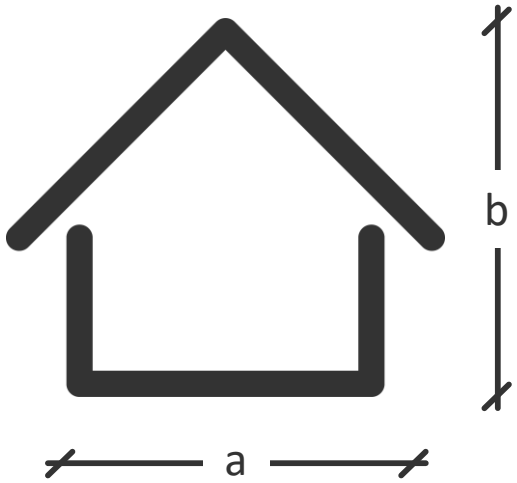

CONSTRAINTS

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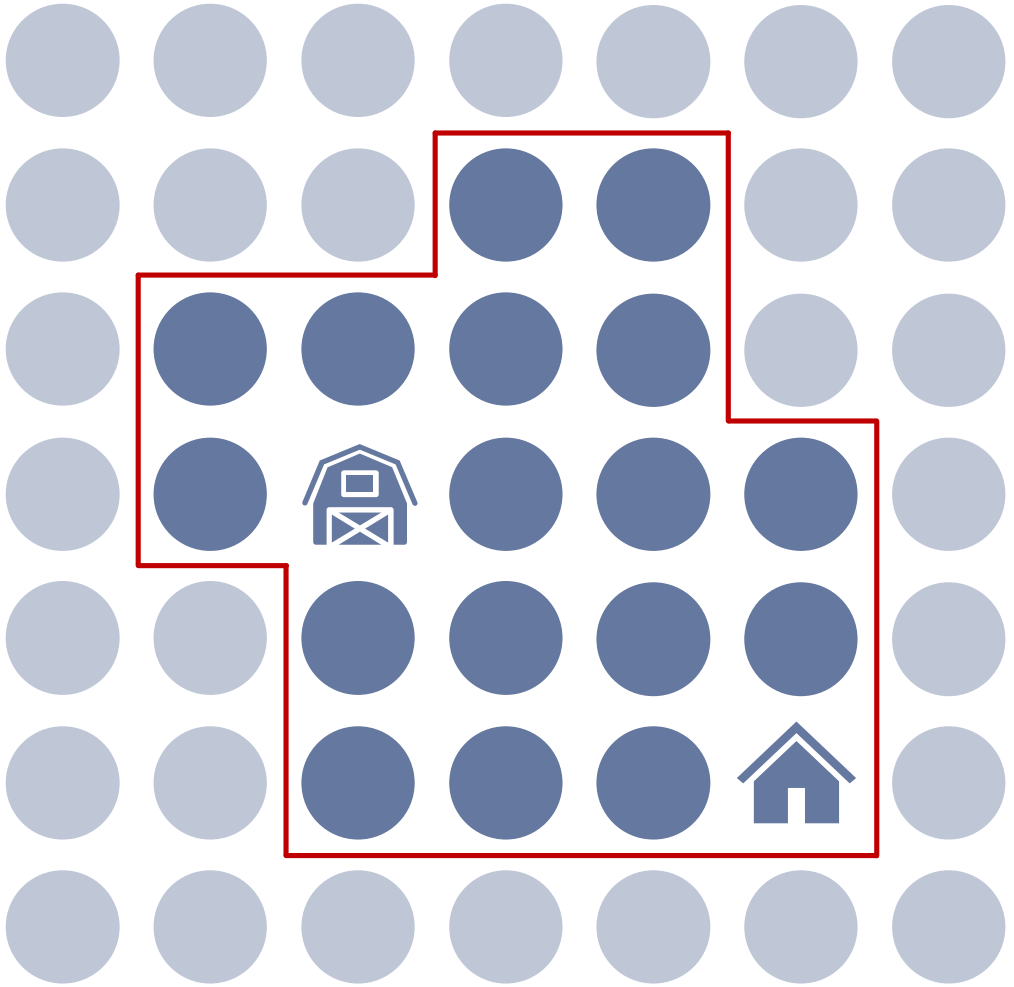
b $[b_1 , b_2]$



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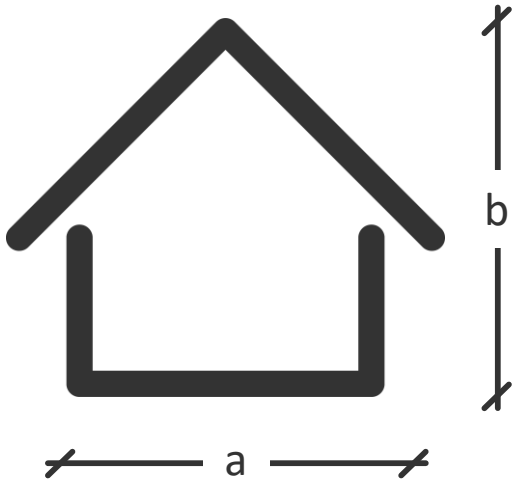
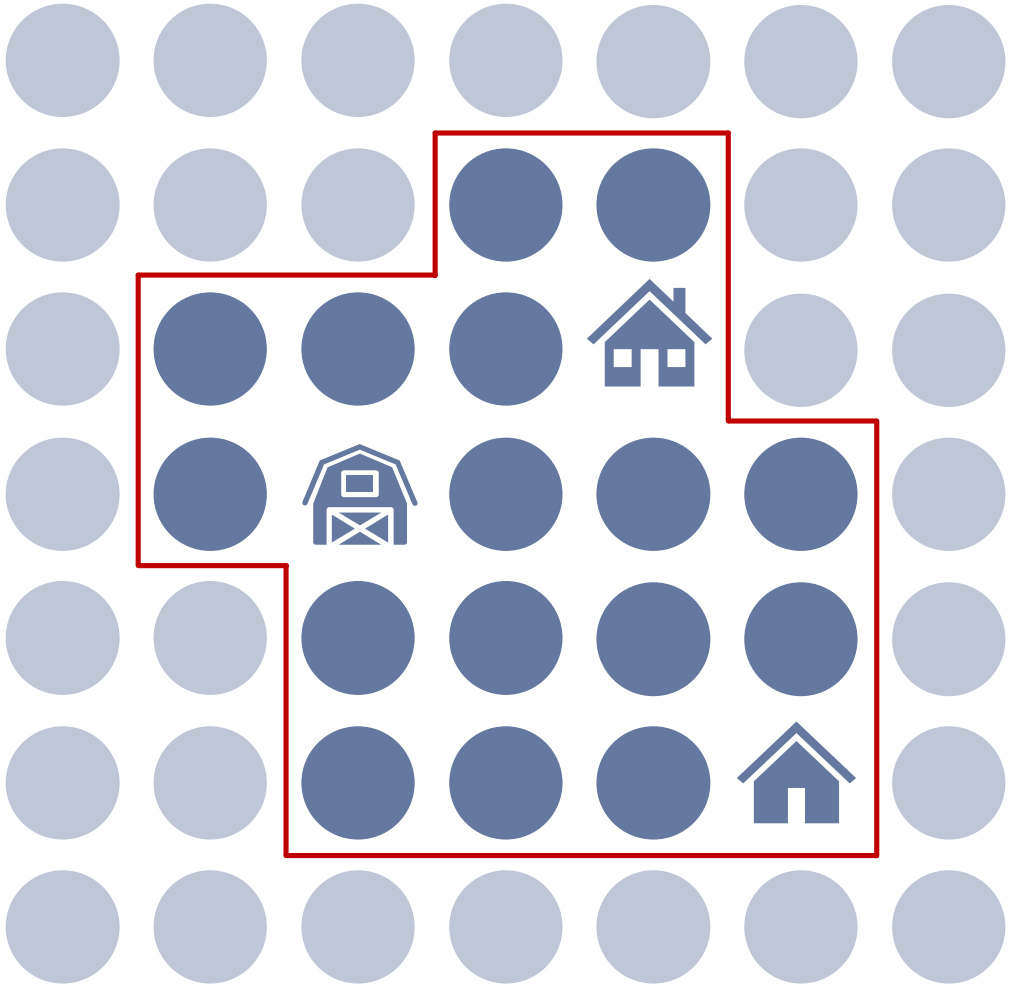


CONSTRAINTS

a $[a_1 , a_2]$

b $[b_1 , b_2]$

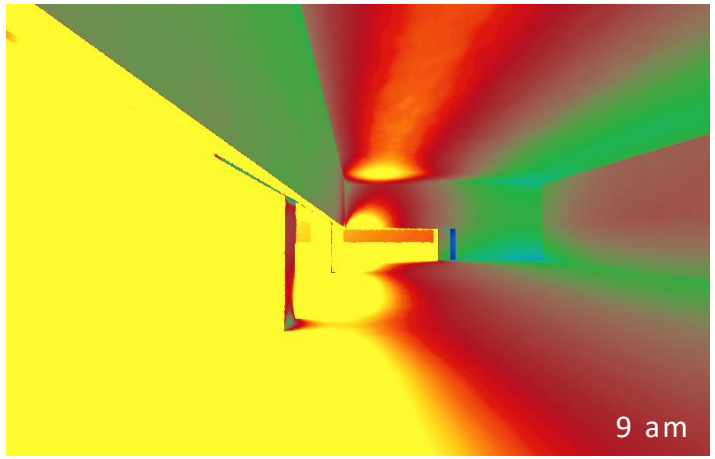


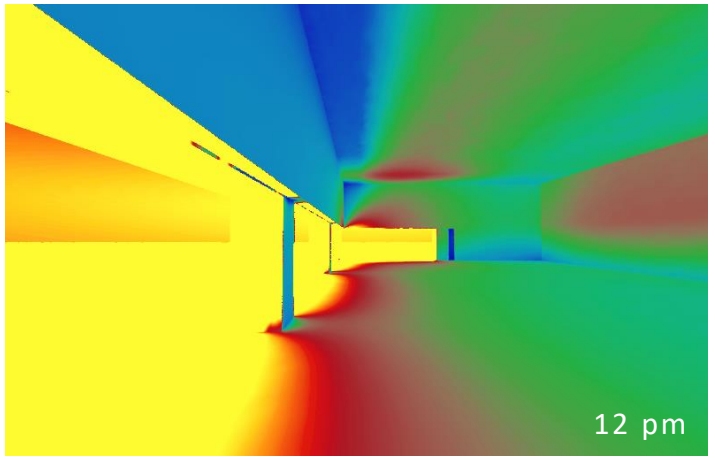
CURRENT CONDITIONS

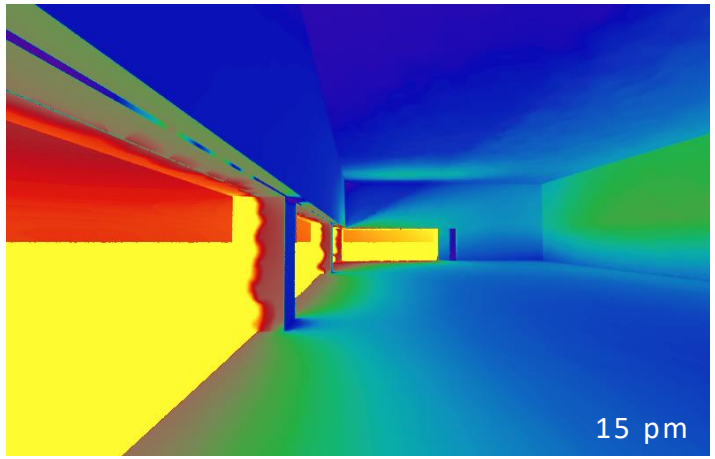
POINT-IN-TIME LUMINANCE

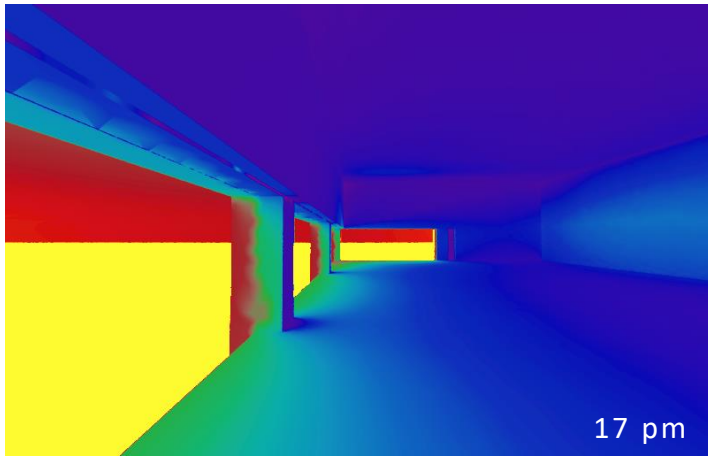
CURRENT CONDITIONS

POINT-IN-TIME LUMINANCE

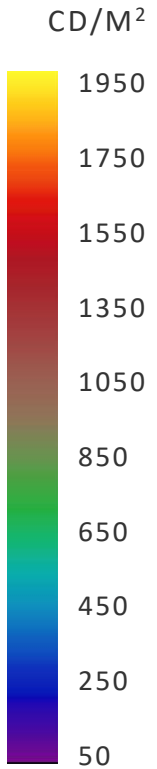






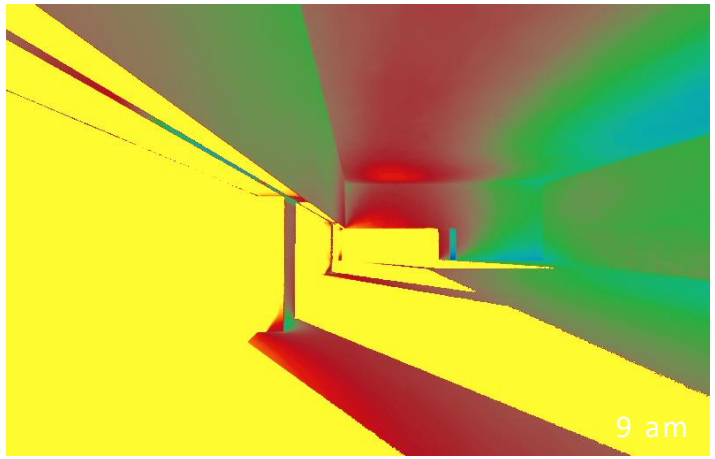


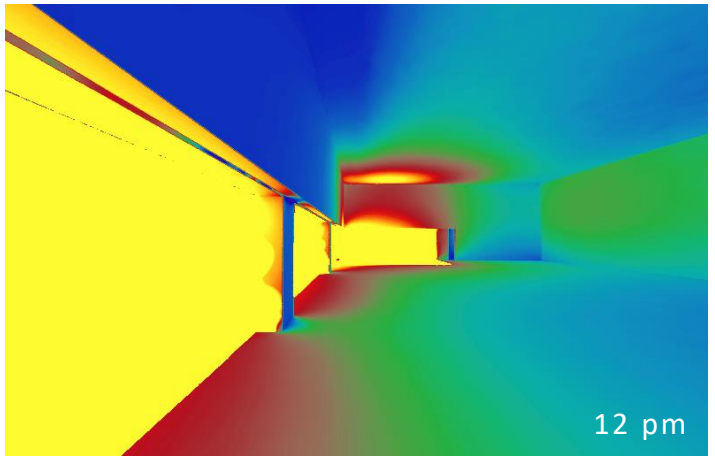
SUMMER SOLSTICE

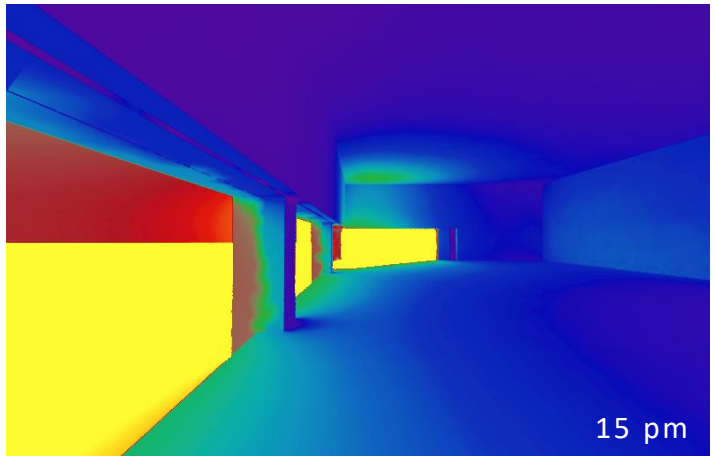


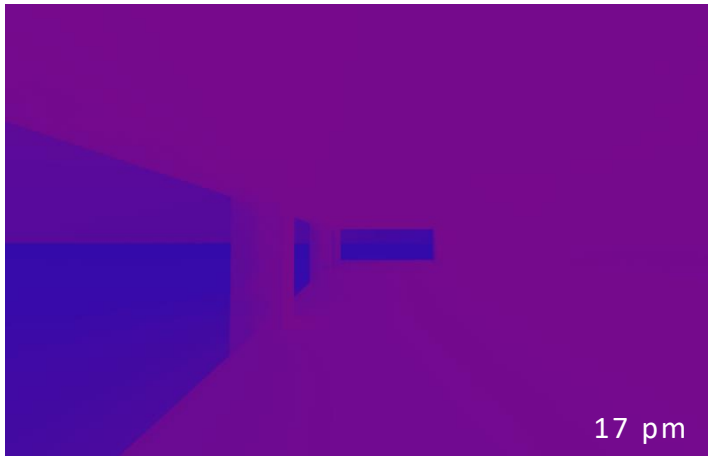
CURRENT CONDITIONS

POINT-IN-TIME LUMINANCE









WINTER SOLSTICE

CD/M²

1950
1750
1550
1350
1050
850
650
450
250
50