THE AMERICAN UNIVERSITY IN CAIRO
الجامعة الأمريكية بالقاهرة

DESIGN OPTIMIZATION USING GENOPT AND DAYSIM

Khaled Nassar & Mohamed Aly
THE AMERICAN UNIVERSITY IN CAIRO
DEPARTMENT OF CONSTRUCTION AND ARCHITECTURAL ENGINEERING

SEPTEMBER 2014

2014 INTERNATIONAL RADIANCE WORKSHOP
LONDON, UK, SEPTEMBER 1ST TO 3RD

Introduction

The main objective of this presentation is to show how to couple DAYSIM with GENOPT

We demonstrate why is this important with some application examples

Show the mechanics of how this can be done through an example application

Discuss the results of this example using different optimization algorithms

Present some further work that may need to be done

What is GENOPT and DAYSIM

OPTIMIZATION

GenOpt® is an optimization program for the minimization of a cost function that is evaluated by an external simulation program. Also parametric Analysis

Michael Wetter

Lawrence Berkeley National Laboratory

GenOpt

Generic Optimization Program

SIMULATION

DAYSIM is a validated, RADIANCE-based daylighting analysis software that models the annual amount of daylight in and around buildings

Christoph Reinhart

Lawrence Berkeley National Laboratory

DAYSIM

ADVANCED DAYLIGHT SIMULATION SOFTWARE

Why to do we need to couple simulation with optimization

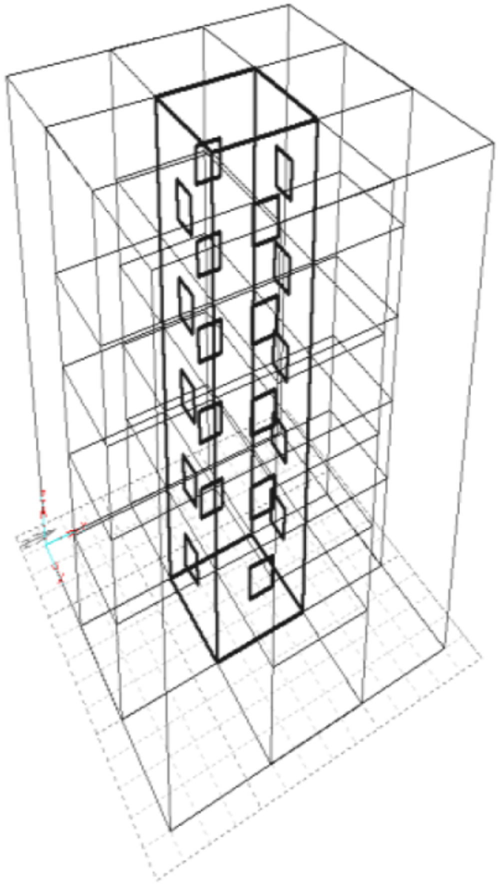
DESIGN OF LIGHTWELL

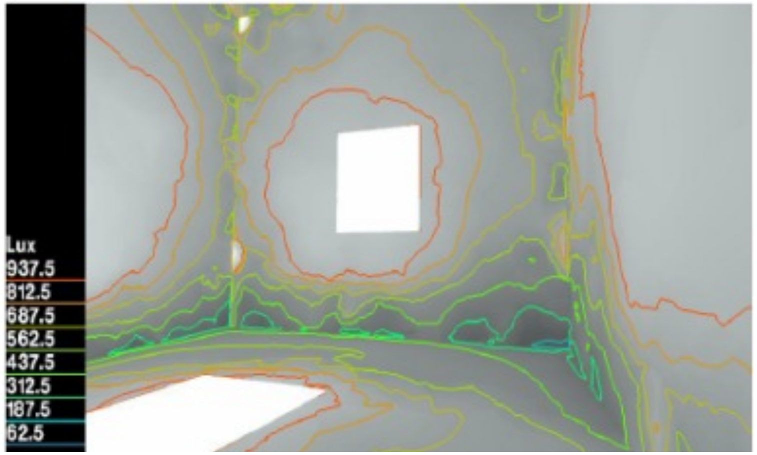
Parametric variations – time consuming – especially if you have to consider different times of day

Example Application A:
DESIGN OF LIGHTWELL

DESIGN VARIABLES

- Dimensions, i.e. Area
- Orientation
- Shape, i.e. wider at the bottom or top
- Reflective Material



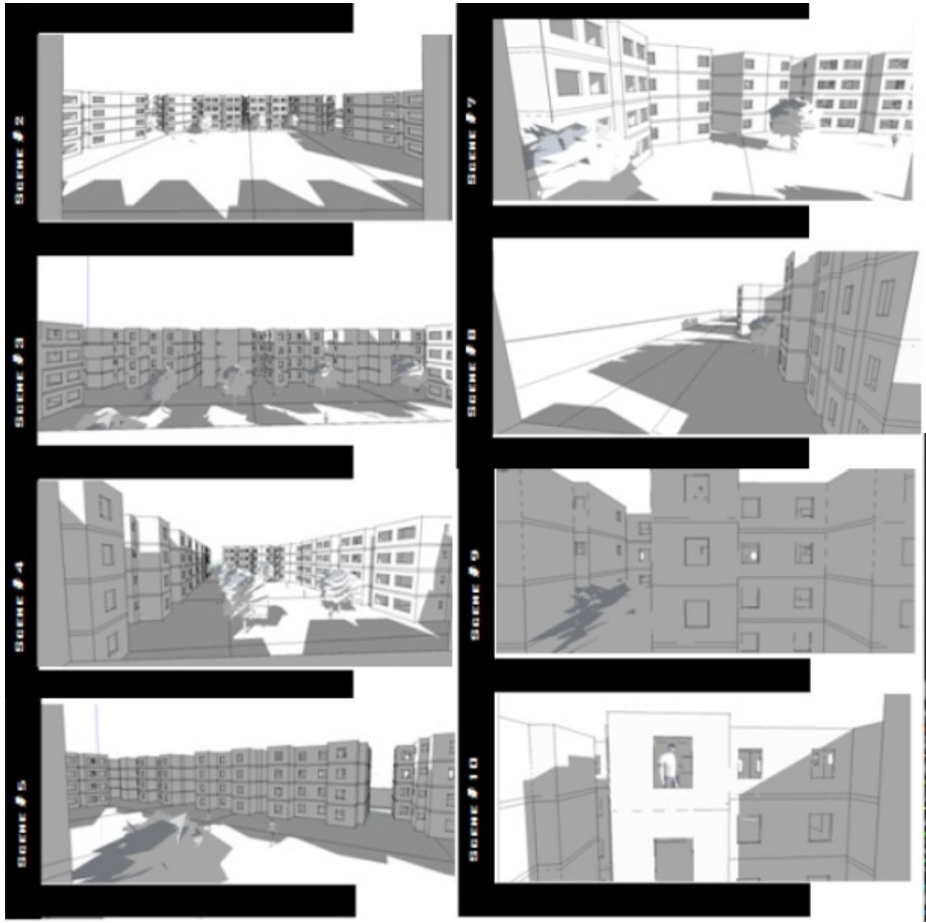


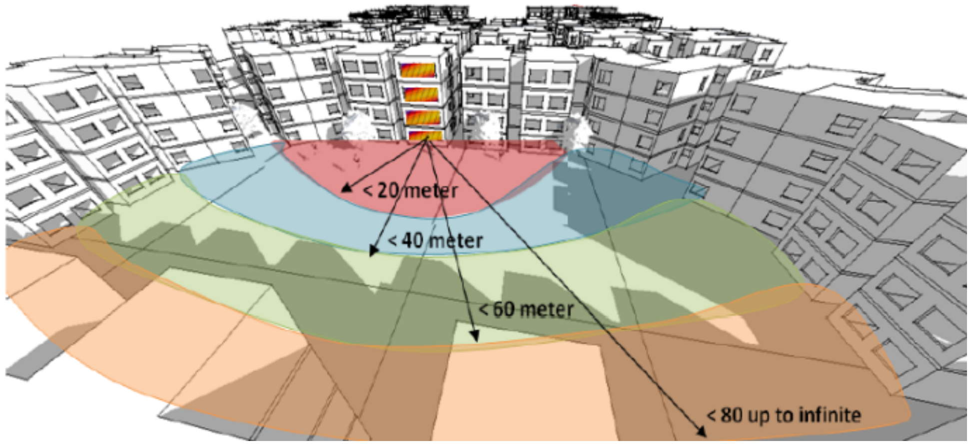
Example Application B:

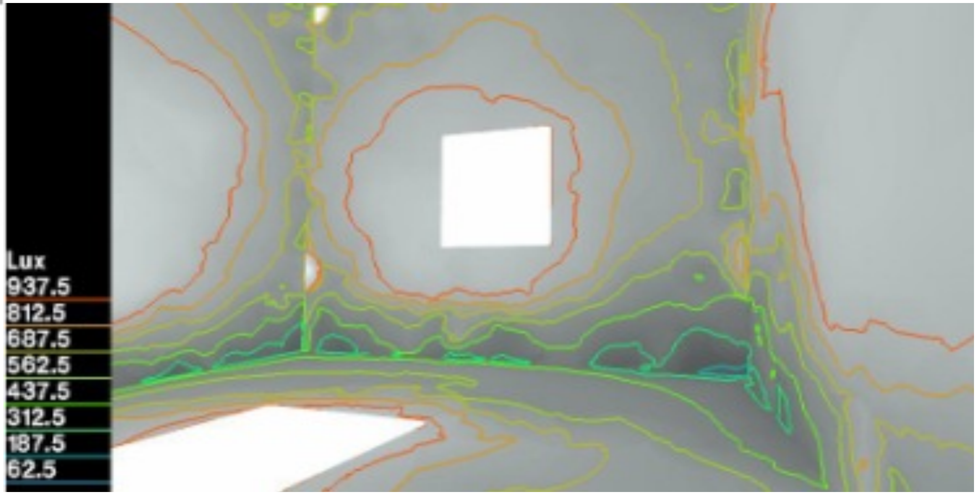
DESIGN OF WINDOW FOR VIEWS AND DAYLIGHT

DESIGN VARIABLES

- Window Dimensions
- Aspect Ratio
- Window Location
- Other Geometry



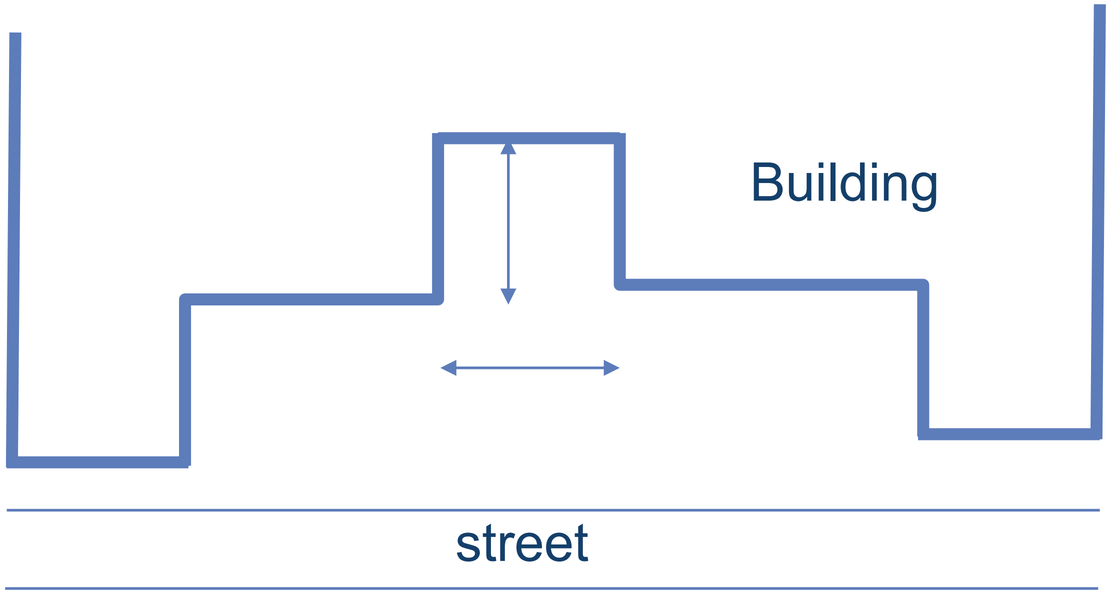


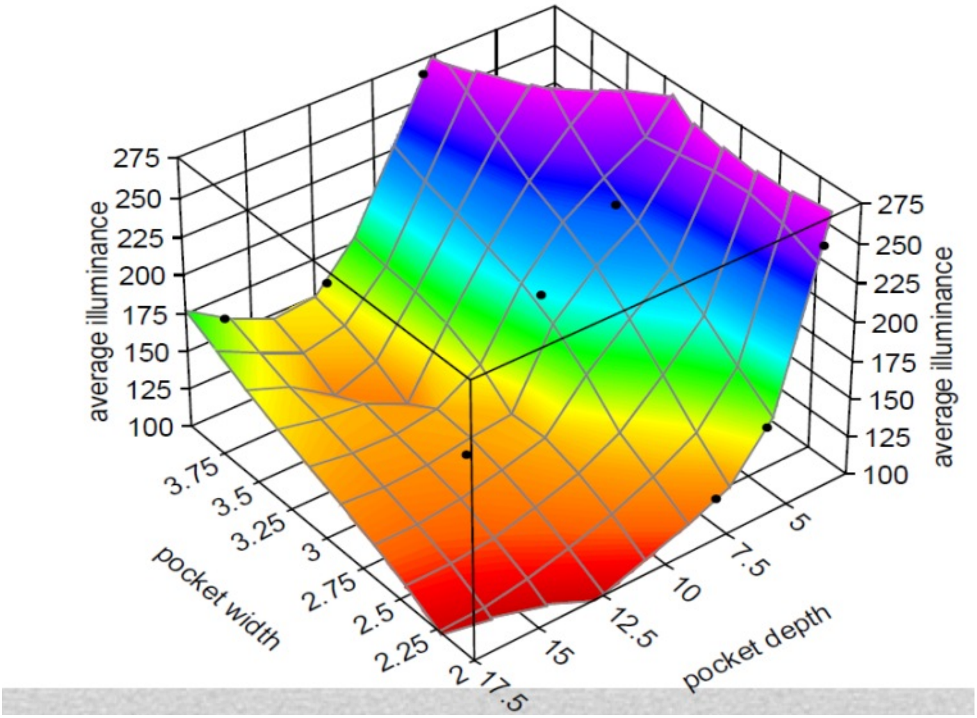


Example Application C:
DESIGN OF LIGHT POCKET

DESIGN VARIABLES

Pocket width and depth





Why DAYSIM

GENOPT has been coupled with any other software

11th workshop we presented how to couple with RADIANCE

Instead of having to consider different times of day and different days around the year

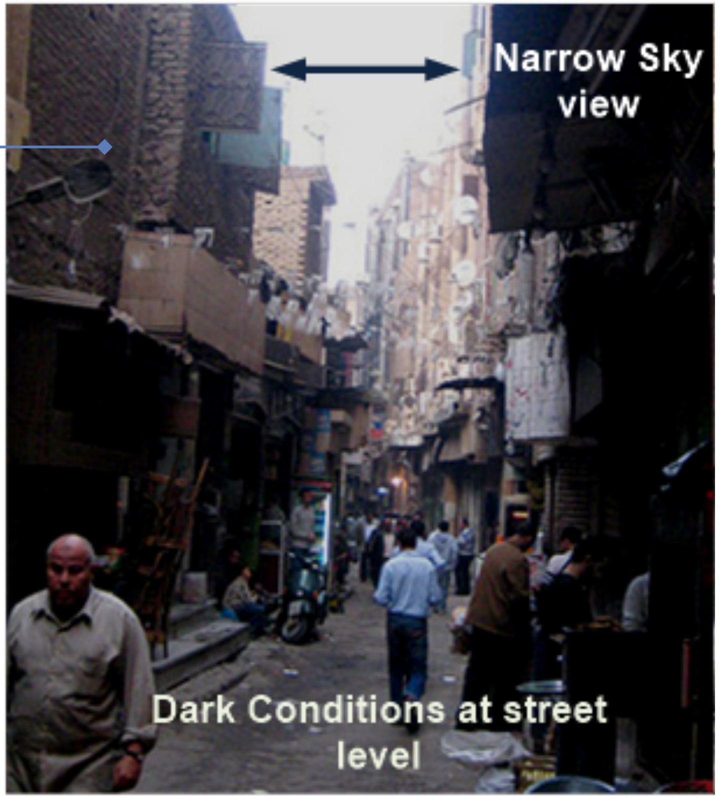
Need Dynamic daylight measures from DAYSIM

Such as Daylight Autonomy, Useful Daylight Index (and in the future perhaps the New IES metrics)

Example Problem Considered here:

Increasing Light in Dense Urban Areas

Unpainted Surfaces, low reflectivity



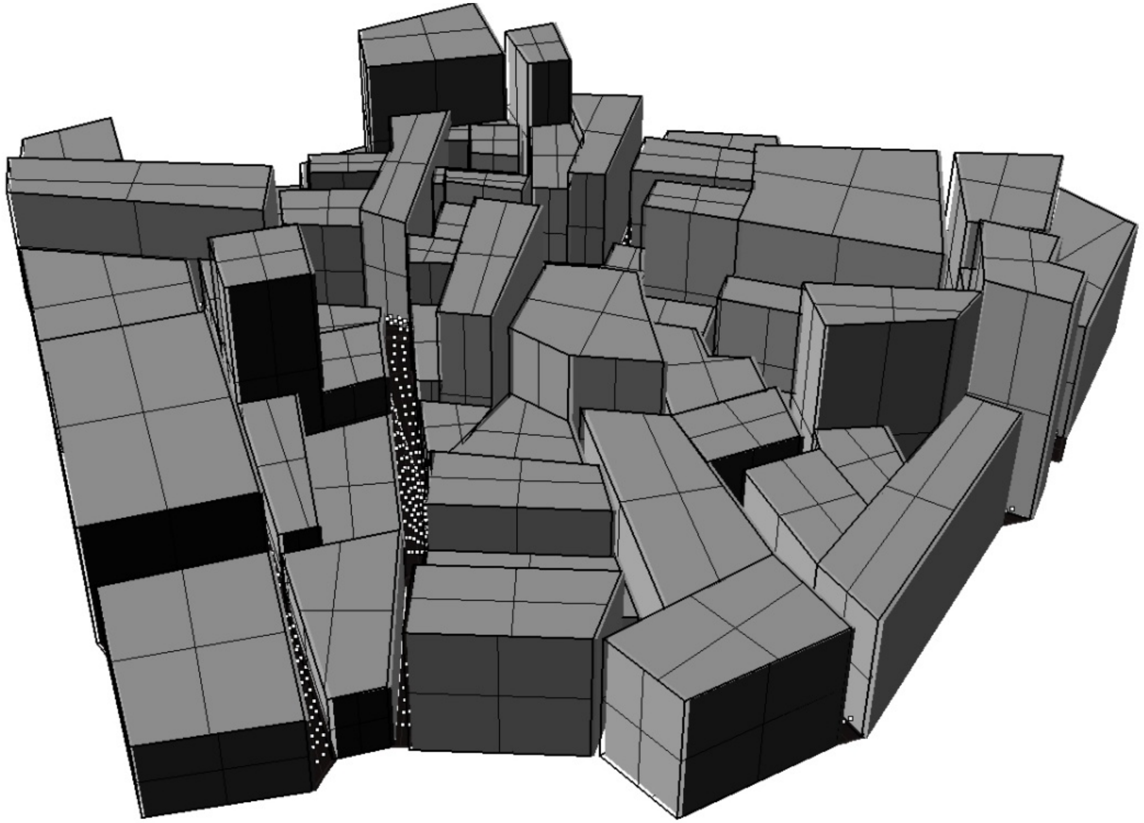
Example Problem Considered here

Which Surface to Finish with Reflective Paint

Given a Limited Budget

Which surfaces can be painted and which should be painted

Variations by adding constraints, costs and types of paint, important areas, etc…



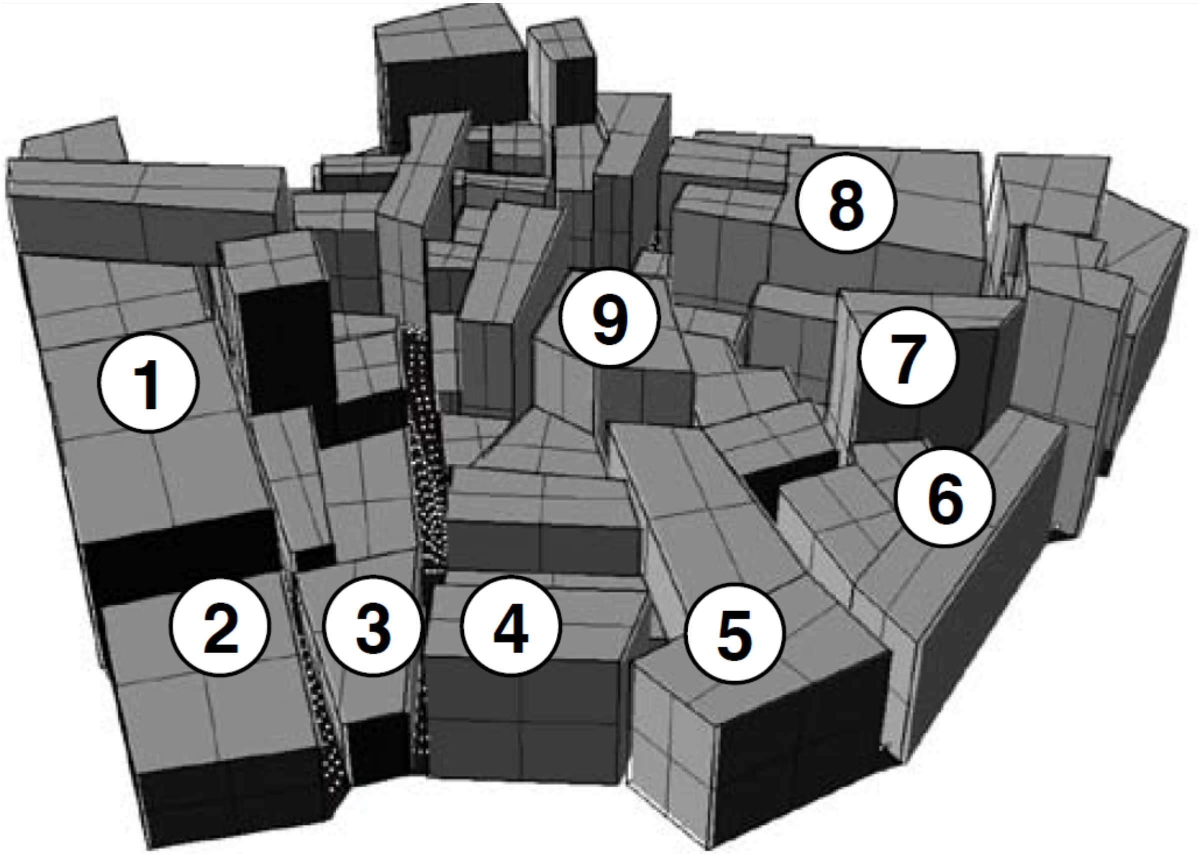
Example Problem Considered here

A Knapsack optimization problem

$$TC = \sum_{i=1}^{m} \sum_{j=1}^{n} C_i^j \times A_i \times x_j, \quad x_j \in \{0,1\}, C_i^1 = 0$$

Where C_i is the unit cost of painting building *i* with paint type *j* and A_i is the area of building i.

x_j is a binary variable to represent whether building *i* will be painted with paint type *j*.



Criteria for Daylighting

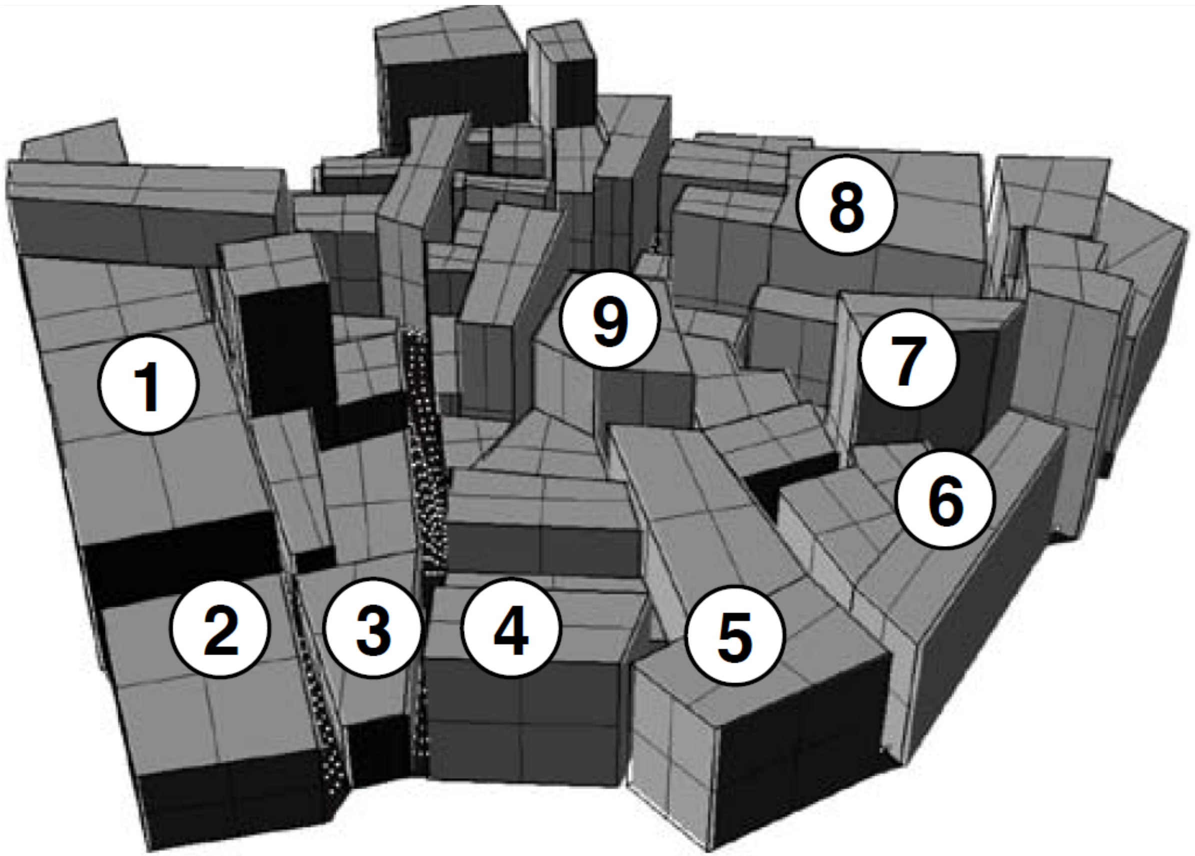
A Knapsack optimization problem

$$Obj = \frac{TC}{D(x_1, x_2 \ldots . x_{jn})}$$

Now *D* can be one of many daylight criteria in the street level:

- Daylight Autonomy (DA): percentage of working hours when a minimum work plane illuminance is maintained by daylight alone
- Useful Daylight Illuminances (UDI): divides working hours

Or we could even look at values in the inside of the rooms



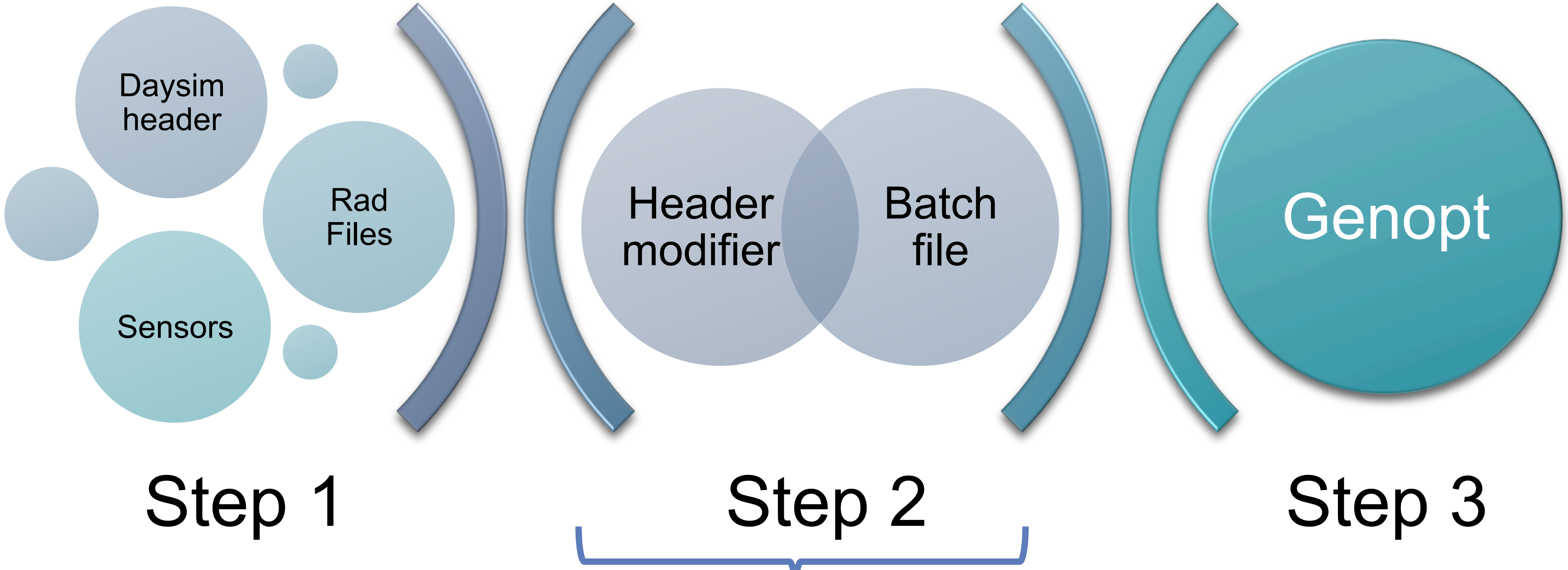
Criteria for Daylighting

Goal Programming for Multi-Criteria

$$Obj = w1 \times \left[\frac{TC - TC_{target}}{TC}\right] + w2 \times \left[\frac{D_{target} - D}{D_{target}}\right]$$

D is simply the annual average illuminance and D_{target} is the set value, i.e. 10,000lux

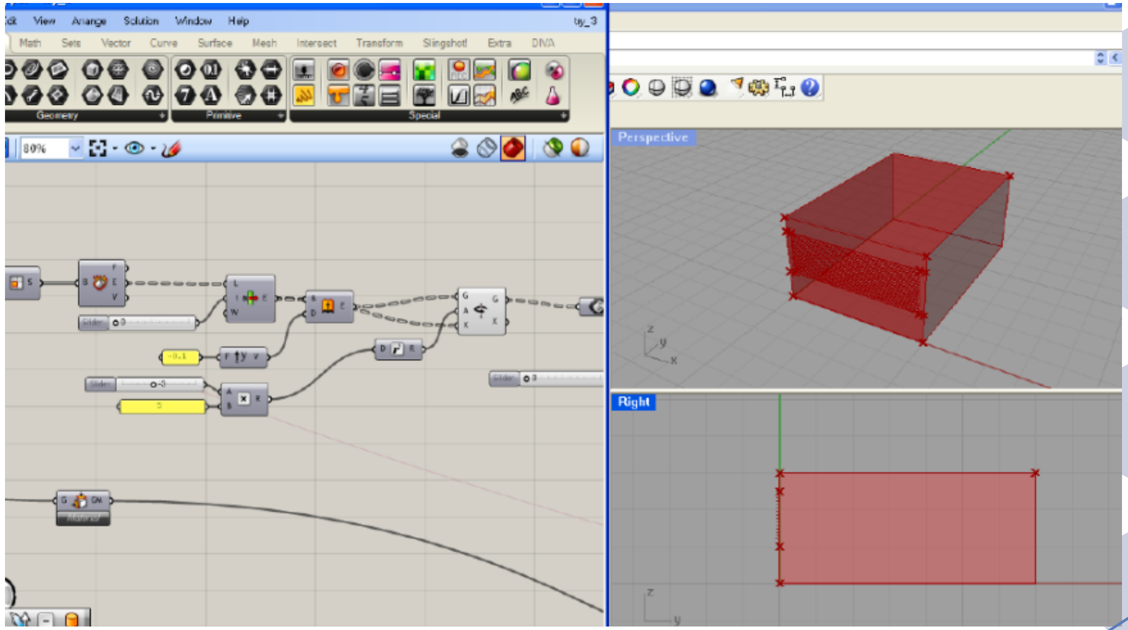
The Mechanics of how GENOPT works with DAYSIM (and other software)



Will be made available with this presentation

DAYSIM Files

DAYSIM Modeling and creating the required files



1. C:\~\material.rad,
2. C:\~\geometry.rad

- Daysim_header_file.hea
- Daysim_material.rad
- Daysim_geometry.rad
- Daysim_sensor.pts
- Occupancy_file.csv
- Radiance Source Files
- Others

DAYSIM Files (what you have to change)

Specifying parameters

```
#Grasshopper Geometry
#Scene File written: 02/13/2013 11:45:30

facade_%refl%PercentReflectance polygon 000
0
0
9
      -1.509174  15.22416  15
      -1.509174  15.22416  0
      -1.507891  20.35717  15
............
...............
facade_%refl%PercentReflectance polygon 0002
```

What about changing the geometry of the model itself

Mood polygon wall_S1

0

0

12

%dimension1..

%dimension2..

%dimension3..

VARRY DIMENSIONS

Mood polygon wall_S1

0

0

12

5 ${val1 *2+1} 0

0 ${val1 *2+1} 0

0 ${val1 *2+1} 1

5 ${val1 *2+1} 1

..

PARAMETRIC VARIATION

A. The Header Modifier

```
@echo off
setlocal enabledelayedexpansion
set INTEXTFILE=Daysim_header_file.hea
set OUTTEXTFILE=Daysim_header_file1.hea
set SEARCHTEXT=Mfile1
set REPLACETEXT=project_directory    %~dp0
set OUTPUTLINE=

for /f "tokens=1,* delims=¶" %%A in ( '"type %INTEXTFILE%"') do (
SET string=%%A
SET modified=!string:%SEARCHTEXT%=%REPLACETEXT%!
echo !modified! >> %OUTTEXTFILE%
)
del %INTEXTFILE%
rename %OUTTEXTFILE% %INTEXTFILE%
```

project_directory C:\~\tmp-genopt-run-1

Mfile1 = marker for one of the header files

A. The Header Modifier

```
@echo off
setlocal enabledelayedexpansion
set INTEXTFILE=Daysim_header_file.hea
set OUTTEXTFILE=Daysim_header_file1.hea
set SEARCHTEXT=Mfile 2
set REPLACETEXT=tmp_directory        %~dp0
set OUTPUTLINE=
..........
................
...............................
```

Remainder of the Header Modifier
Could be written for any system (linux, mac etc…)

tmp_directory   C:\~\tmp-genopt-run-1

Mfile2 = marker for one of the header files

B. The Batch File

```
@ echo off
SET RAYPATH=.;C:\Radiance\lib;C:\Radiance\bin;C:\DaysimBinaries;$RAYPATH
SET PATH=.;C:\Radiance\lib;C:\Radiance\bin;C:\DaysimBinaries;$PATH
C:
CD C:\DIVA\DaysimBinaries
epw2wea  %~dp0EGY_Cairo.623660_IWEC.epw %~dp0EGY_Cairo.623660_IWEC.wea
:: 1. Import Radiance File
radfiles2daysim %~dp0Daysim_header_file.hea -m -g
:: 2. Calculation Daylight Coefficients File (*.dc)
gen_dc %~dp0Daysim_header_file.hea –dif –dir -paste
CD C:\~\DaysimBinaries
:: 3. Generate Illuminance File (*.ill)
ds_illum %~dp0Daysim_header_file.hea
:: 4. Generate Dynamic Controls and Daylighting Outputs
gen_directsunlight %~dp0Daysim_header_file.hea
ds_el_lighting.exe %~dp0Daysim_header_file.hea
exit
```

GENOPT FILES

- OptWinXP.ini
  Initialization File
- RadianceWinXP.cfg
  Configuration File
- Command.txt
  Command File

GenOpt Files

1. OptWinXP.ini

   This is the main file that tells GenOpt where to find the actual project files, the location of the objective function in the results.

2. RadianceWinXP.cfg

   This file is the ine that tells to tell GenOpt how to call the program from the command line and the correct syntax for that

3. Command.txt

   This file has two main functions:

   1. to tell GenOpt which parameters to change and how to change them (i.e. ranges, steps).

   2. To specify the optimization algorithm to be used and its parameters

A. Initialization File

```
Simulation {
  Files {
   Template {
      File1 = direct_radiance_file.tmp_template.rad;
      File2 = skyPatches_template.rad;
      File3 = Daysim_geometry_template.rad;
      File4 = Daysim_material_template.rad;
      File5 = material_template.rad;
      File6 = Daysim_sensor.pts;
      File7 = Daysim_template.vf;
      File8 = Daysim_template.bat;
      File9 = Daysim_template.hea;
      File10 = Daysim_template.rad;
      File11 = 8to6with_occ_template.csv;
      File12 = error_template.dat;
      File13 = EGY_Cairo.623660_IWEC_template.epw;
   }
```

These are the template files given to the program

A. Initialization File

```
Input {
    File1 = direct_radiance_file.tmp.rad;
      SavePath1 = Save;
      File2 = skyPatches.rad;
    SavePath2 = Save;
      File3 = Daysim_geometry.rad;
    SavePath3 = Save;
      File4 = Daysim_material.rad;
    SavePath4 = Save;
      File5 = material.rad;
    SavePath5 = Save;
      File6 = Daysim_sensor.pts;
    SavePath6 = Save;
              ..........
  }
  Log {
    File1 = error.dat;
  }
```

These are the file edited and saved for the simulation

A. Initialization File

```
Output {
    File1 = Daysim_autonomy.DA;
  }
  Configuration {
    File1 = "RadianceWinXP.cfg";
  }
}
………
}
ObjectiveFunctionLocation
{
    Name1      = fitness;
    Function1 = "divide( %fitness2% , %fitness1%)";
    //Name2      = fitness1;
    //Function2 = "add( %fitness13% , %fitness4% , %fitness3% ,
    %fitness6% , %fitness7% , %fitness8% , %fitness9%)";


    Name2      = fitness1;
    Function2 = "add( %fitness16% , %fitness15%)";
```

Initialization File

```
Name2       = fitness1;
Function2 = "add( %fitness16% , %fitness15%)";

Name3       = fitness2;
Function3 = "add( %Da1% , %Da2% , %Da3% , %Da4% , %Da5% ,
%Da6%)";

Name4       = Da6;
Delimiter4 = “delimiterofyourchoice";

………
Function10 = "multiply( %refl% , 20)";

…………..
Name22       = fitness15;
Function22 = "add( %fitness9% , %fitness10% , %fitness11%)";
…………
```

B. RandianceWin Config

```
SimulationStart
{

    Command = "%Simulation.Files.Log.Path1%/Run_Batch-file.bat";
    WriteInputFileExtension = true;
    }
```

If you wanted to access any of the files you defined in the initialization file you can access them here

C. Command File

```
Vary{
Parameter
{
Name     = refl;
Min      = 0;
Ini      = 40;
Max      = 80;
Step     = 20;
}
Parameter{
………….
OptimizationSettings
{
MaxIte = 2000;
MaxEqualResults = 100;
}……………..
```

```
Algorithm{
Main = GPSHookeJeeves;
  MeshSizeDivider = 2;
  InitialMeshSizeExponent = 0;
  MeshSizeExponentIncrement = 1;
  NumberOfStepReduction = 4;
}
```

Solve the Problem Using Particle Swarm Algorithms

```
    For each particle
    Initialize particle
END

Do
    For each particle
        Calculate fitness value
        If the fitness value is better than its peronal best
            set current value as the new pBest
    End

    Choose the particle with the best fitness value of all as gBest
    For each particle
        Calculate particle velocity according equation (a)
        Update particle position according equation (b)
    End
While maximum iterations or minimum error criteria is not attained
```

Results using Particle Swarm Algorithms

Particle Swarm Algorithm parameters:

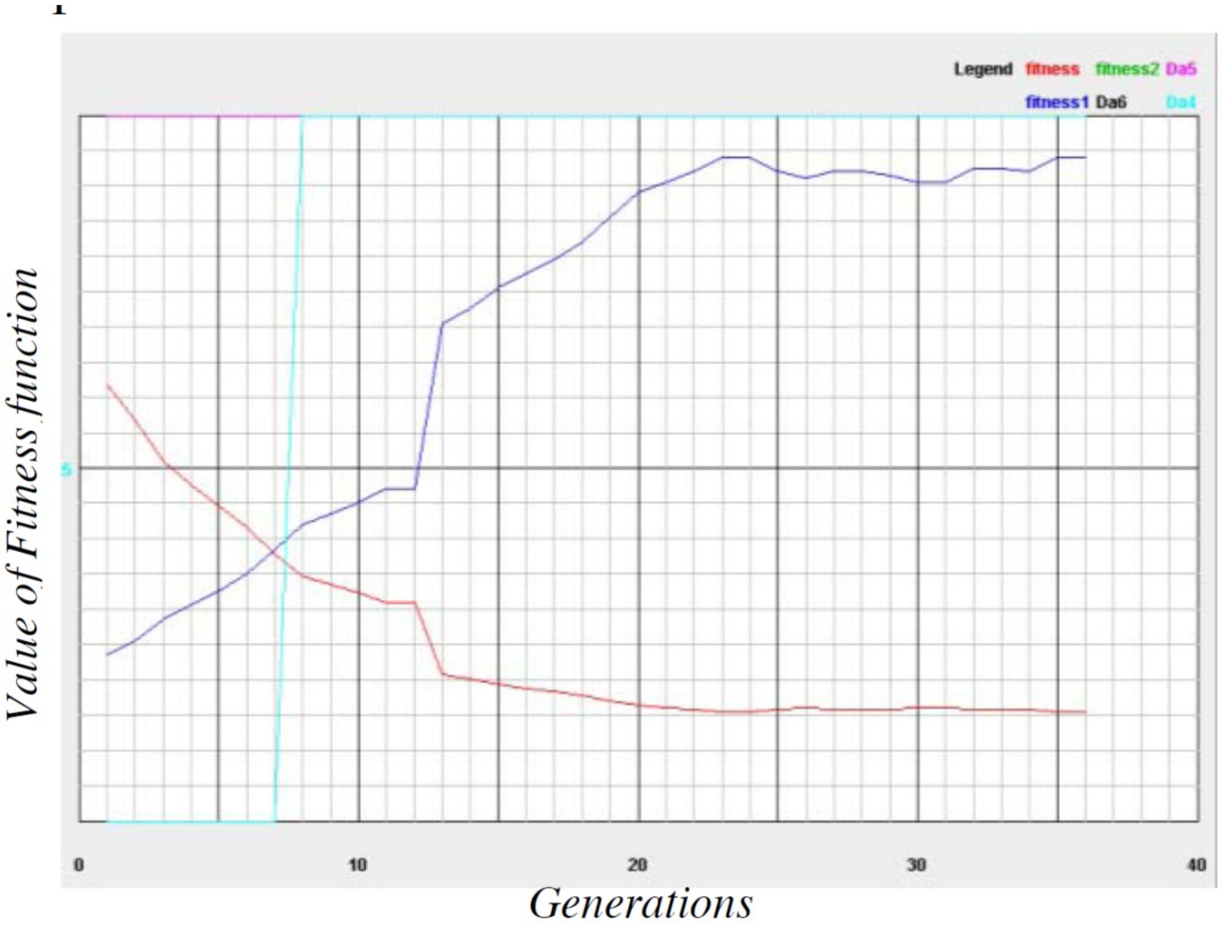
Number of particles (swarm size) = 50

C1 (importance of personal best) = 1

C2 (importance of neighborhood best) = 3

Blue = Normalized Daylight

Red = Normalized Cost

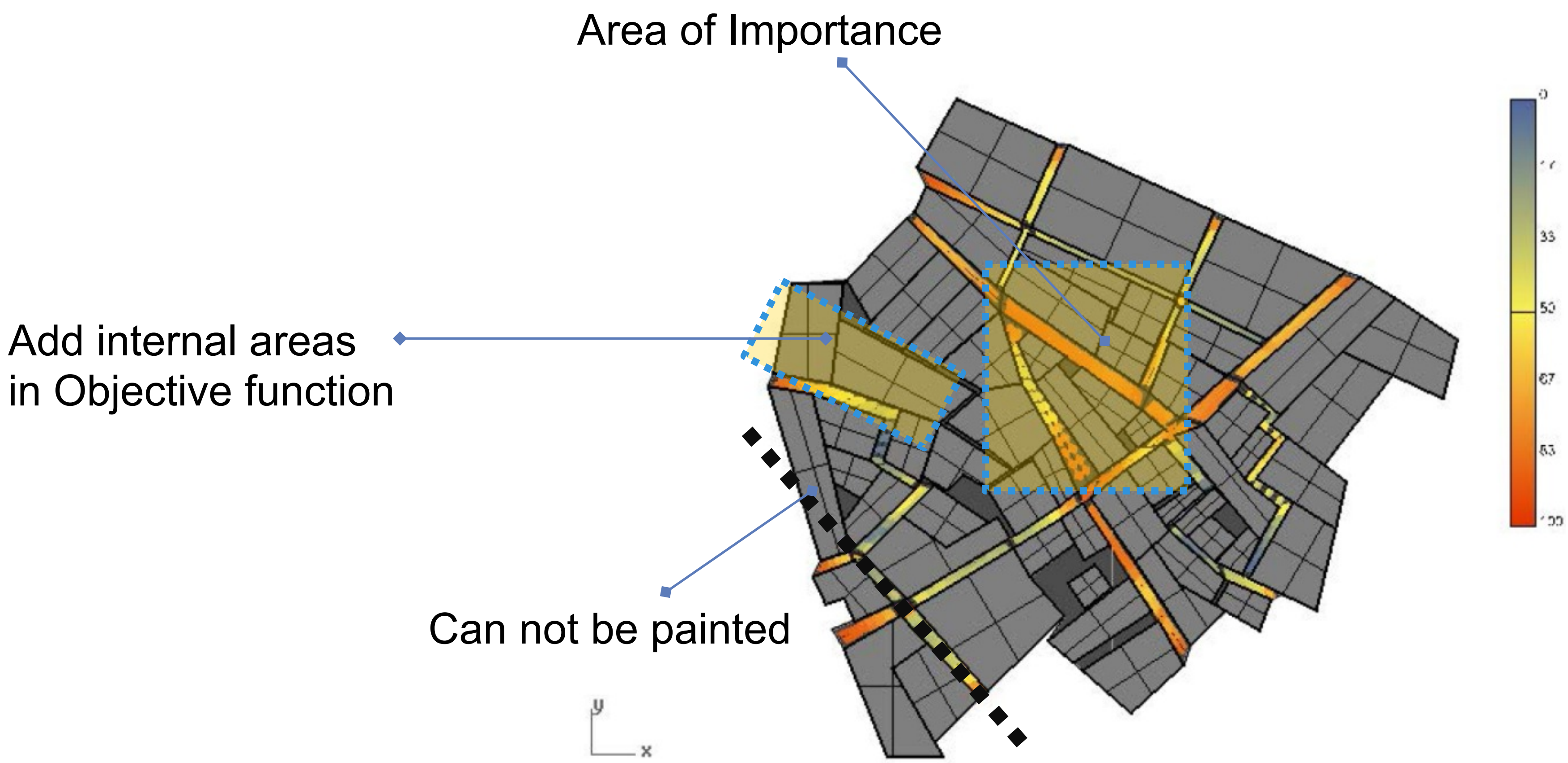


Results

Before

After

Possible change in the Objective Function



Results using Different Optimization Algorithms

N, number of surfaces	Generalized Pattern Search	Particle Swarm	Hybrid Global Optimization
10	1	1	1
100	0.88	0.91	0.91
1000	0.75	0.83	0.79

Normalized Value of Daylight Component of the objective function after convergence

Future: What about BSDF material and geometry

Simulation and Optimization can be a very powerful tool

Benefits of annual simulation metrics from DAYSIM

Next step: Can you use GENOPT to optimize the geometry of BSDF material for CFS?

We could vary the shape of the BSDF material and observe the results for an annual simulation

Also tie in GENOPT with a three or five-phase method to optimize the shape of a BSDF material

Questions