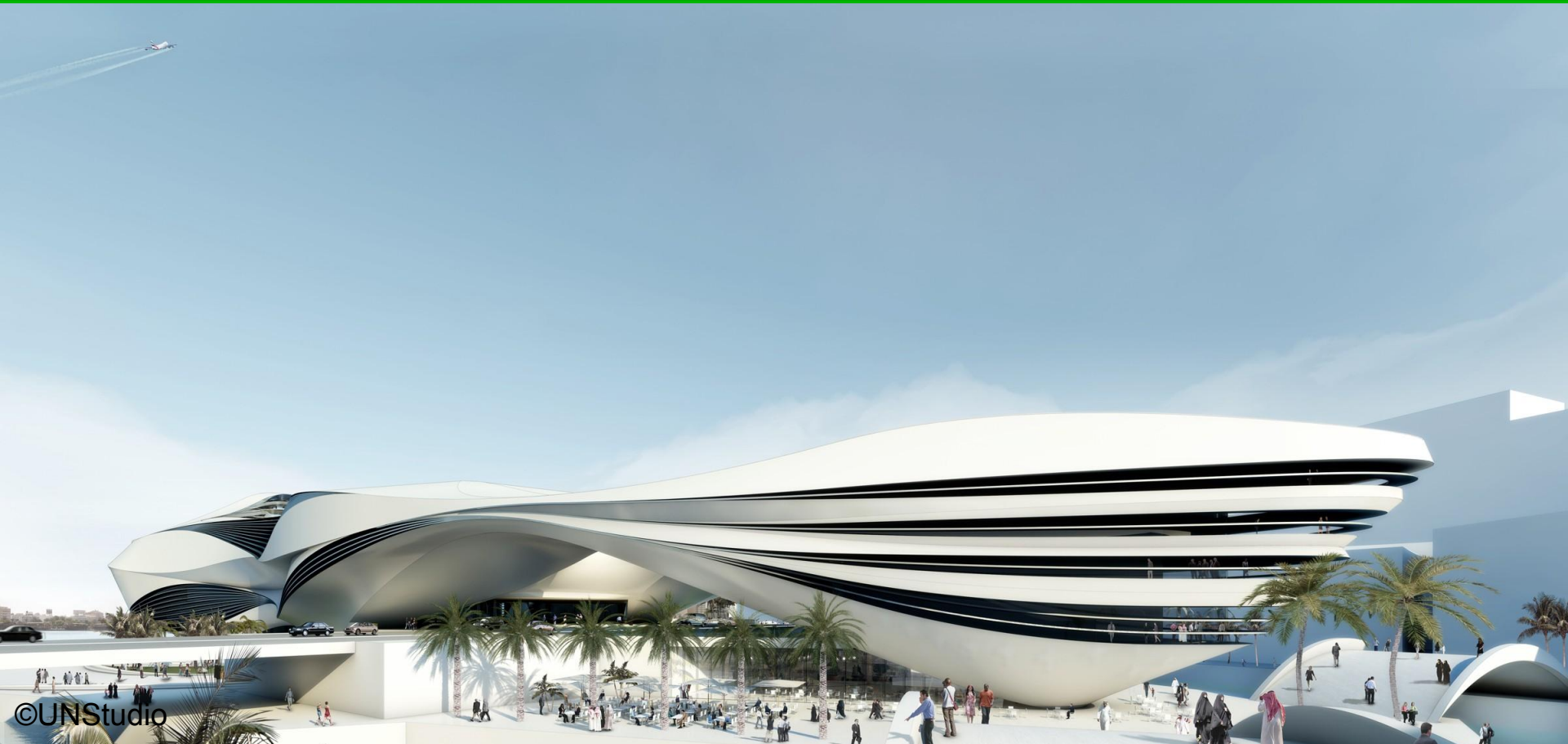
TÉCNICO LISBOA

inesc id lisboa

Generative Design for Building Information Modeling

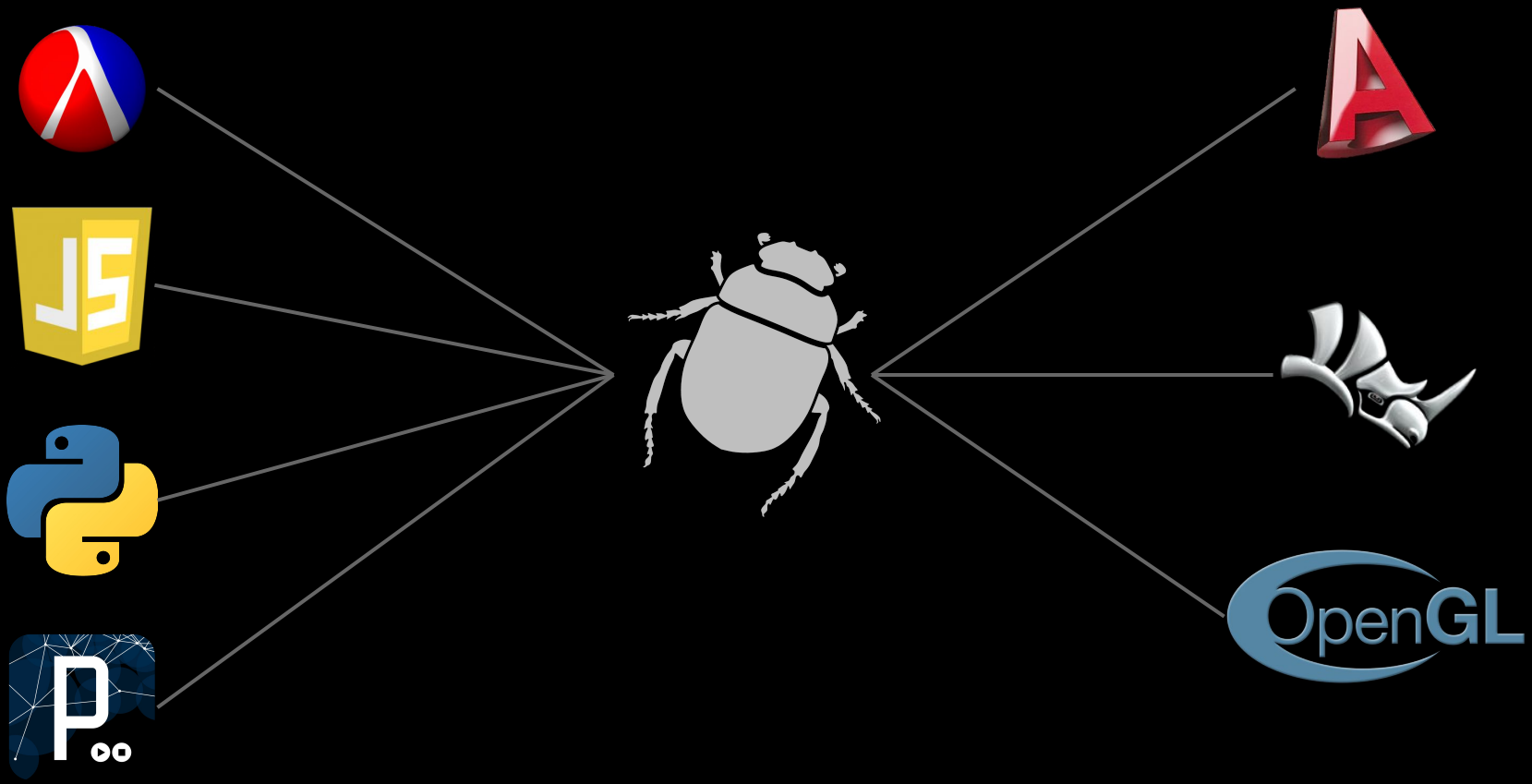
Bruno Ferreira
Supervisor: António Menezes Leitão

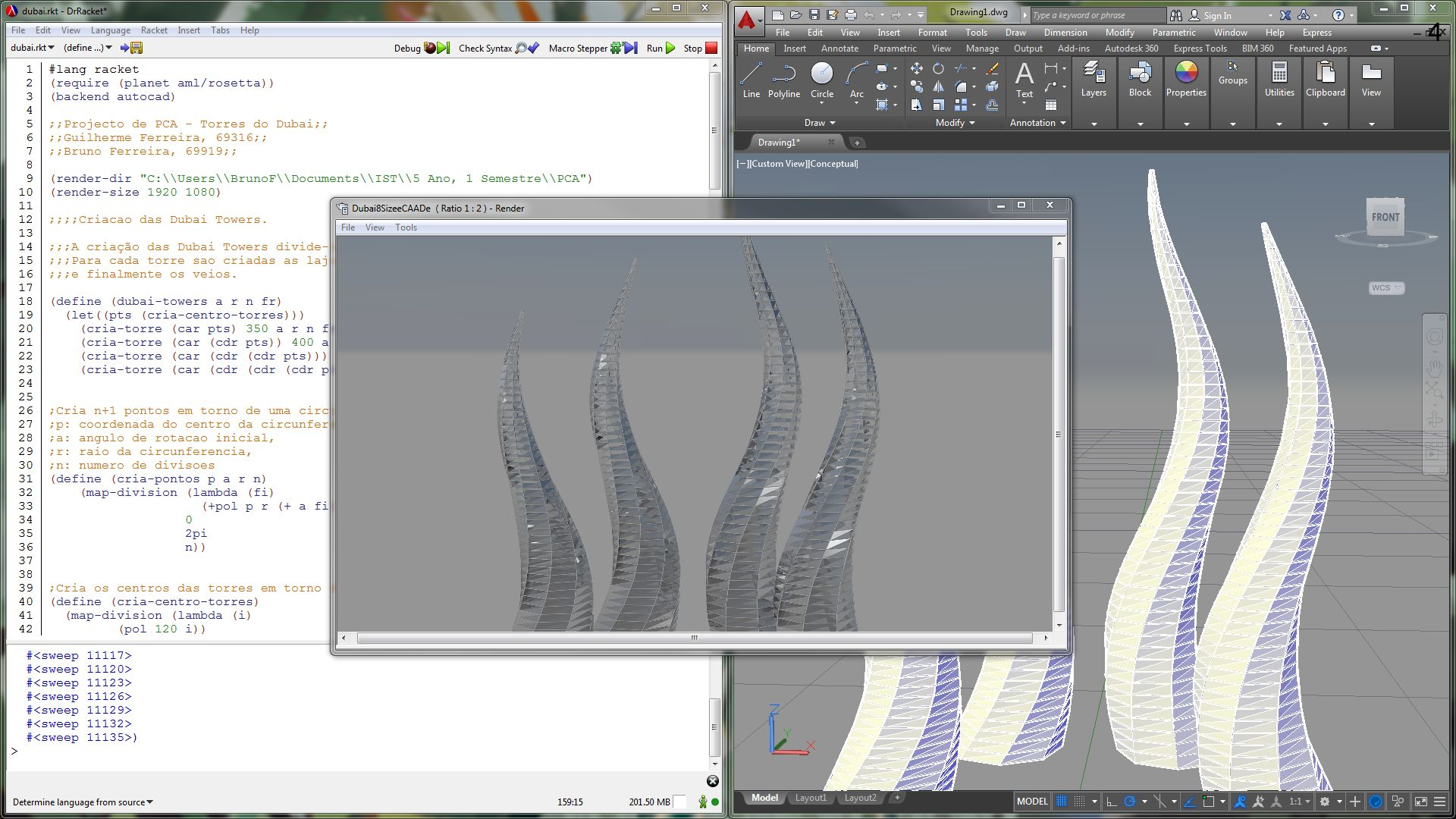
Generative Design



©UNStudio

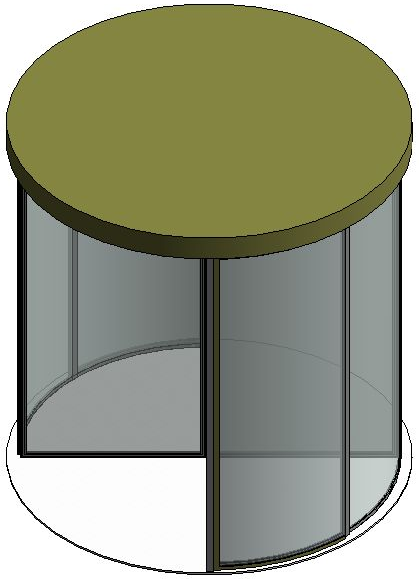
Rosetta

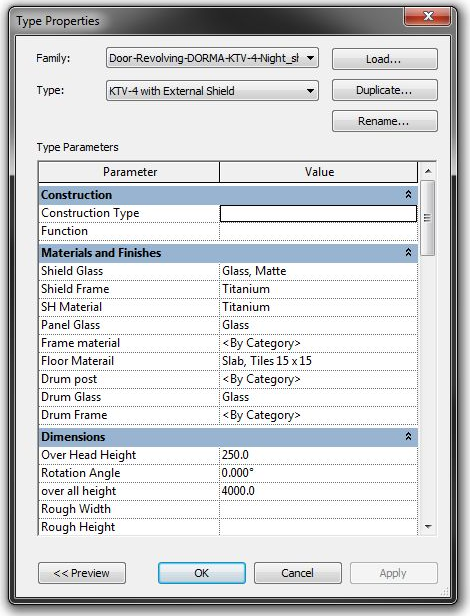



dubai.rkt - DrRacket*
File Edit View Language Racket Insert Tabs Help
dubai.rkt (define ...)
Debug Check Syntax Macro Stepper Run Stop
#lang racket
(require (planet aml/rosetta))
(backend autocad)
;;Projecto de PCA - Torres do Dubai;;
;;Guilherme Ferreira, 69316;;
;;Bruno Ferreira, 69919;;
(render-dir "C:\\Users\\BrunoF\\Documents\\IST\\5 Ano, 1 Semestre\\PCA")
(render-size 1920 1080)
;;;;Criacao das Dubai Towers.
;;;A criação das Dubai Towers divide-
;;;Para cada torre sao criadas as laj
;;;e finalmente os veios.
(define (dubai-towers a r n fr)
(let((pts (cria-centro-torres)))
(cria-torre (car pts) 350 a r n f
(cria-torre (car (cdr pts)) 400 a
(cria-torre (car (cdr (cdr pts)))
(cria-torre (car (cdr (cdr (cdr p
;Cria n+1 pontos em torno de uma circ
;p: coordenada do centro da circunfer
;a: angulo de rotacao inicial,
;r: raio da circunferencia,
;n: numero de divisoes
(define (cria-pontos p a r n)
(map-division (lambda (fi)
(+pol p r (+ a fi
0
2pi
n))
;Cria os centros das torres em torno
(define (cria-centro-torres)
(map-division (lambda (i)
(pol 120 i))
#<sweep 11117>
#<sweep 11120>
#<sweep 11123>
#<sweep 11126>
#<sweep 11129>
#<sweep 11132>
#<sweep 11135>)
>
Determine language from source
159:15
201.50 MB
DubaiSizeeCAADe (Ratio 1 : 2) - Render
File View Tools
Drawing1.dwg
File Edit View Insert Format Tools Draw Dimension Modify Parametric Window Help Express
Home Insert Annotate Parametric View Manage Output Add-ins Autodesk 360 Express Tools BIM 360 Featured Apps
Line Polyline Circle Arc
Draw
Modify
Text
Annotation
Layers
Block
Properties
Groups
Utilities
Clipboard
View
Drawing1*
[−][Custom View][Conceptual]
FRONT
WCS
Model Layout1 Layout2
MODEL

Disadvantages

Building Information Modeling




Type Properties
Family: Door-Revolving-DORMA-KTV-4-Night_sl
Load...
Type: KTV-4 with External Shield
Duplicate...
Rename...
Type Parameters
Parameter
Value
Construction
Construction Type
Function
Materials and Finishes
Shield Glass Glass, Matte
Shield Frame Titanium
SH Material Titanium
Panel Glass Glass
Frame material <By Category>
Floor Materail Slab, Tiles 15 x 15
Drum post <By Category>
Drum Glass Glass
Drum Frame <By Category>
Dimensions
Over Head Height 250.0
Rotation Angle 0.000°
over all height 4000.0
Rough Width
Rough Height
<< Preview
OK
Cancel
Apply

TOP
FRONT
RIGHT

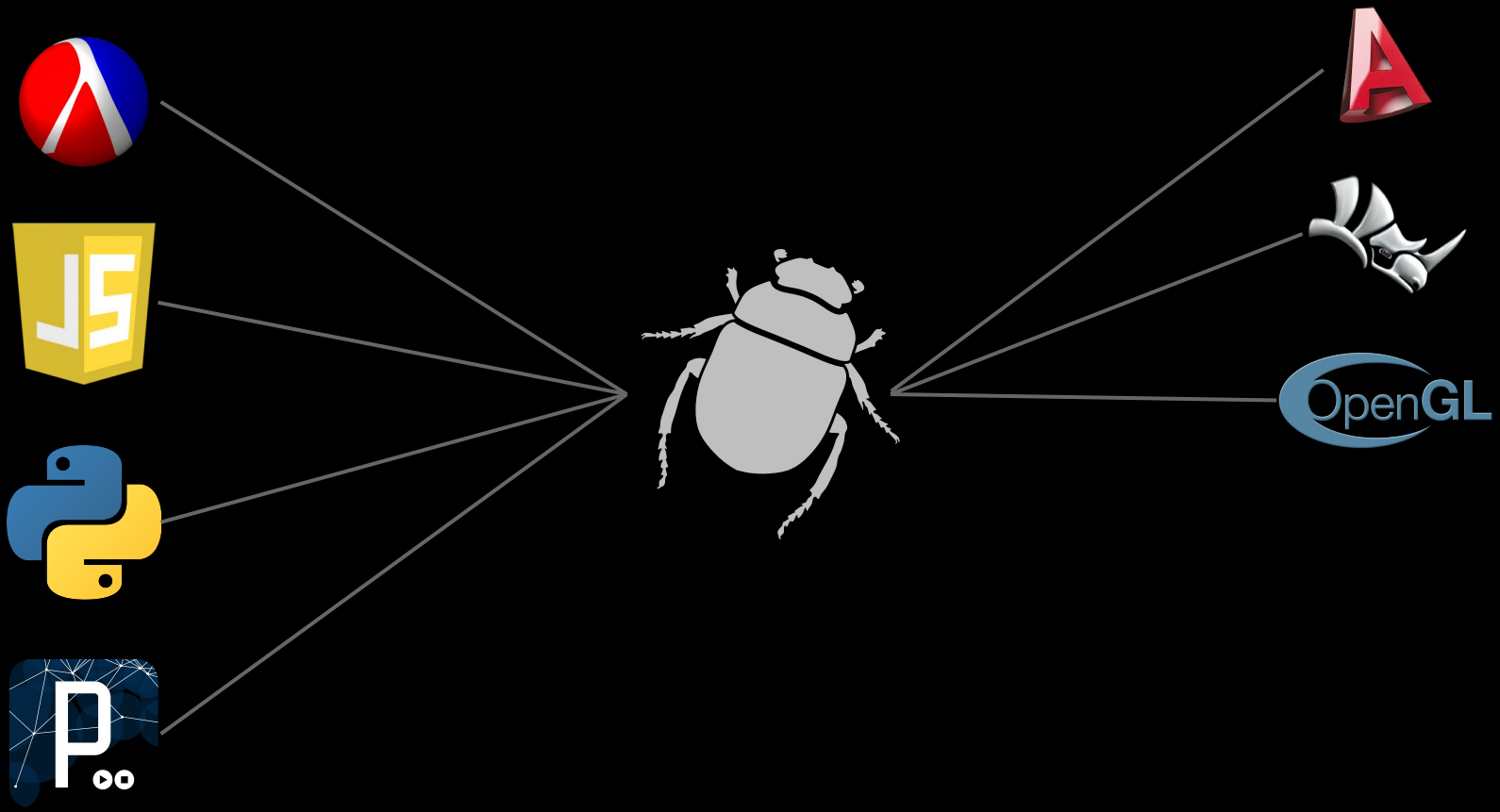
BIM
+
Programming

nbbj
CCDI

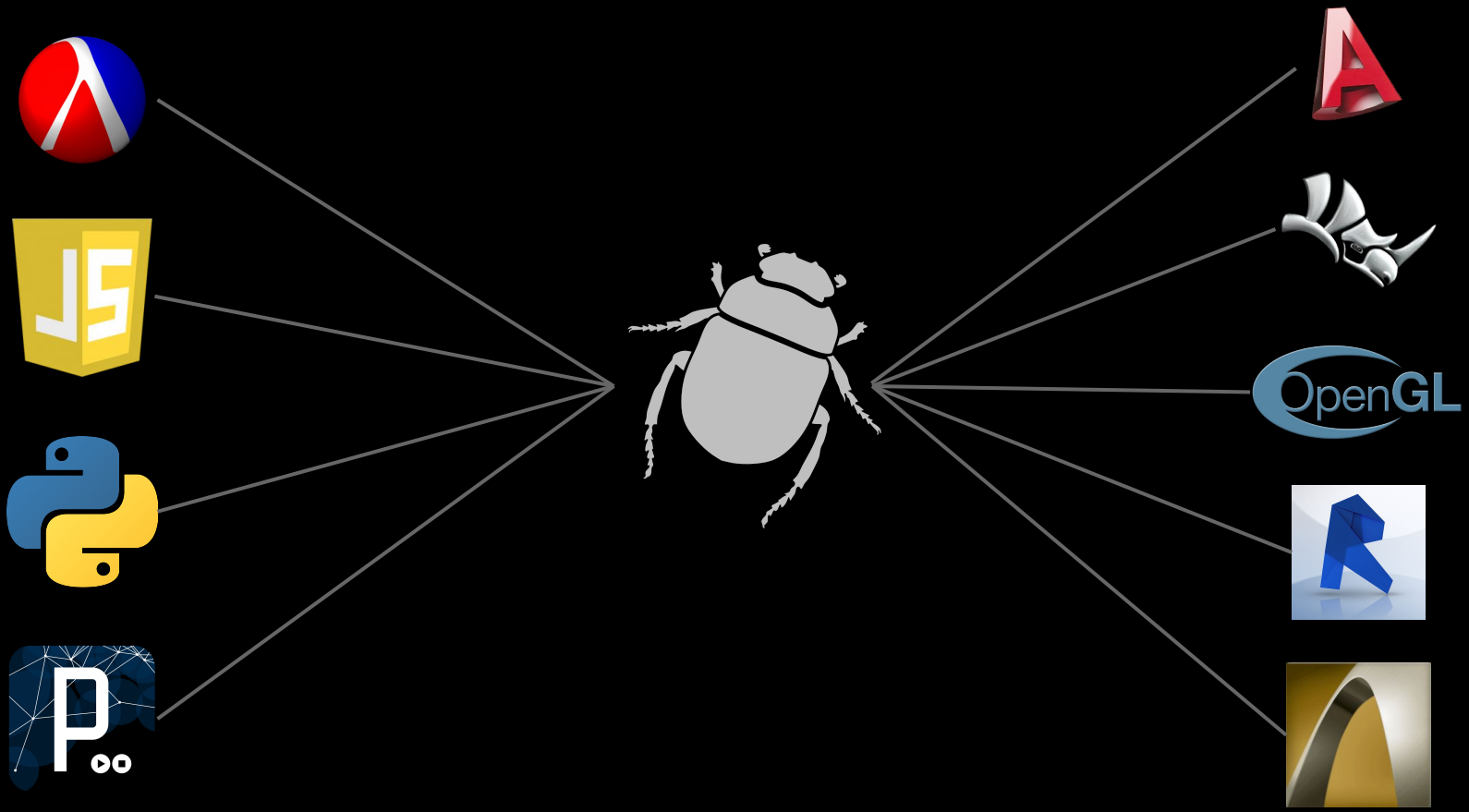
Objectives

- GD programs for BIM
- BIM Abstract Layer

Rosetta



Rosetta



Related Work

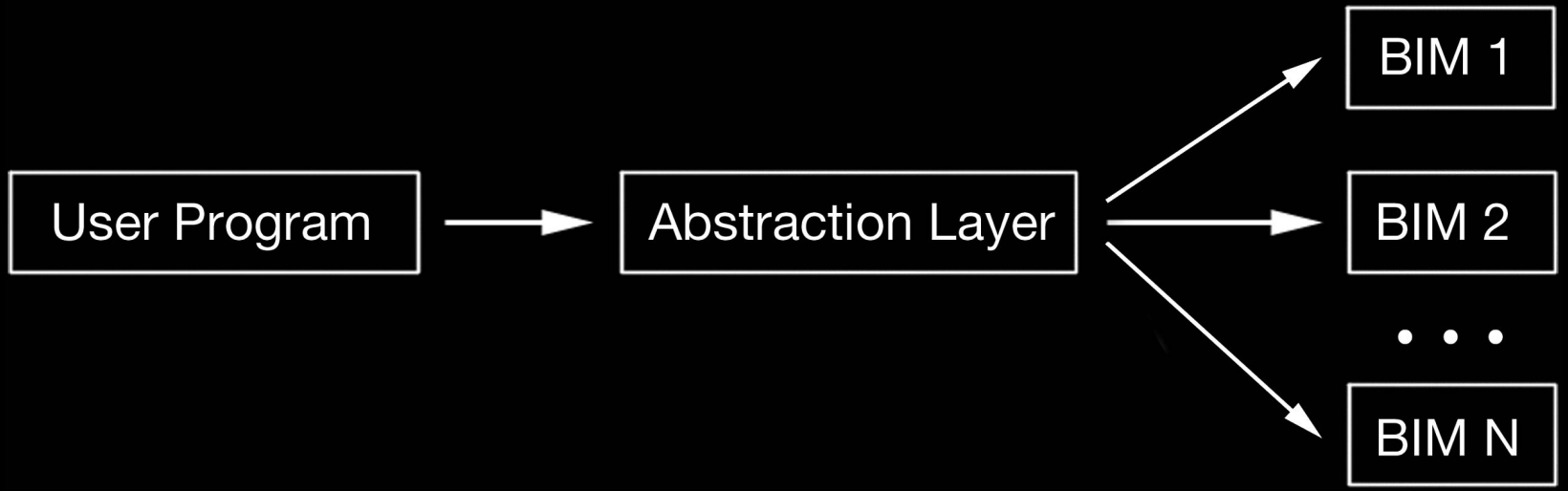
Application	Visual	Textual	BIM Support	Geometric Operations	BIM Operations
Grasshopper	✔	✔–	✗	✔	✗
Lyrebird	✔	✗	✔	✗	✔✔
Dynamo	✔	✔–	✔	✔	✔✔✔
RevitPythonShell	✗	✔	✔	✔	✔✔✔
Rhino-Grasshopper-ArchiCAD	✔	✗	✔	?	✔✔

Problems to Address

- Lack of Scalability
- Inappropriate Programming Tools
- Lack of Portability

Generative Design for BIM

Solution Overview



IDE

edificioCarmoRevit.rkt - DrRacket*

File Edit View Language Racket Insert Tabs Help

edificioCarmoRevit.rkt (define ...) Debug Check Syntax Macro Stepper Run Stop

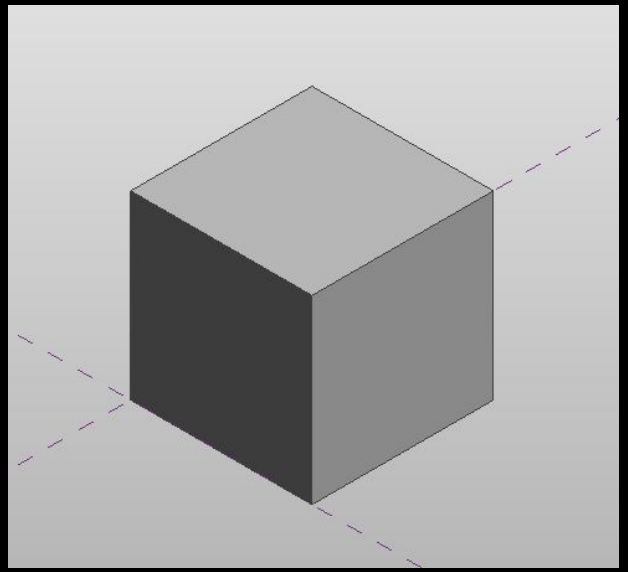
```
1  #lang racket
56         (+ (* (mf m 2 0) (cx p)) (* (mf m 2 1) (cy p)) (* (mf m 2 2) (cz p)) (mf m 2 3))))
57
58  (define (facade-beam p length height n m)
59    (let ((element-length (/ length n))
60          (element-height (/ height m))
61          #;(loc p)
62          (matrix (world-transformation p)))
63      (for/list ((r (range 0 length (/ length n))))
64                (for/list ((z (range 0 height (/ height m))))
65                          (facade-element-beam (+xz p r (+ z (/ element-height 2)))
66                                               element-length
67                                               element-height
68                                               (mm (+ 2000 (* 1000 (cos (+ (* z 2pi (/ 1 height)) (* r 4pi (/ 1 length))))))))))))
69
70  (define (facade-element-beam p width height dist)
71    (let ((e (/ height 2)))
72      (let* ((p0 p)
73             (p1 (+xy p (/ width 2) (- dist))))
74        (let ((v (unitize (p-p p1 p0))))
75          (let* ((pa (+c p0 (v*r v (/ e -2))))
76                 (pb (+c p1 (v*r v (/ e +2)))))
77            (create-beam (loc-in-world pa)
78                         (loc-in-world pb)
79                         #:family (family-element beam-family #:parameter-names (list "b" "d") #:parameter-values (list e e))))))
80      (let* ((p0 (+xz p width e))
81             (p1 (+xyz p (/ width 2) (- dist) e)))
82        (let ((v (unitize (p-p p1 p0))))
```

Welcome to DrRacket, version 6.3.0.2--2015-10-29(3f20803/a) [3m].
Language: racket; memory limit: 128 MB.
>

Determine language from source 70:9 310.02 MB

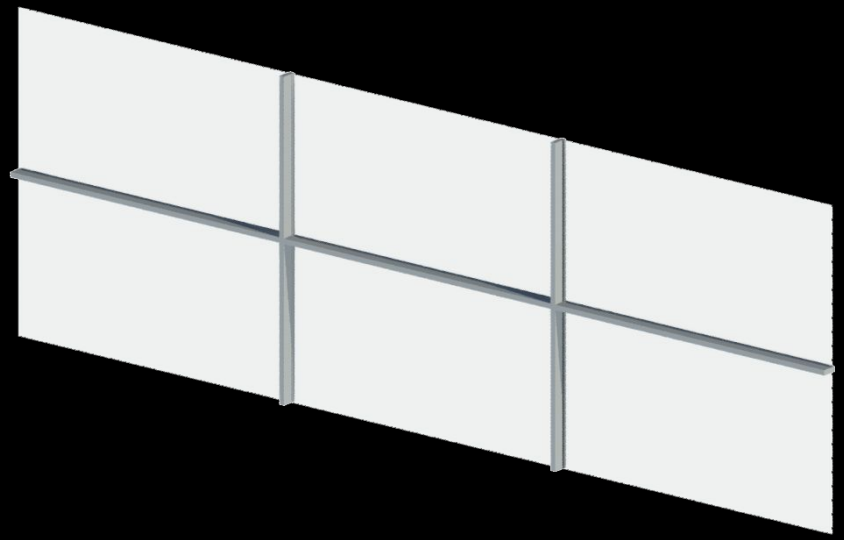
Abstraction Layer

```
(box point
     length
     depth
     height)
```



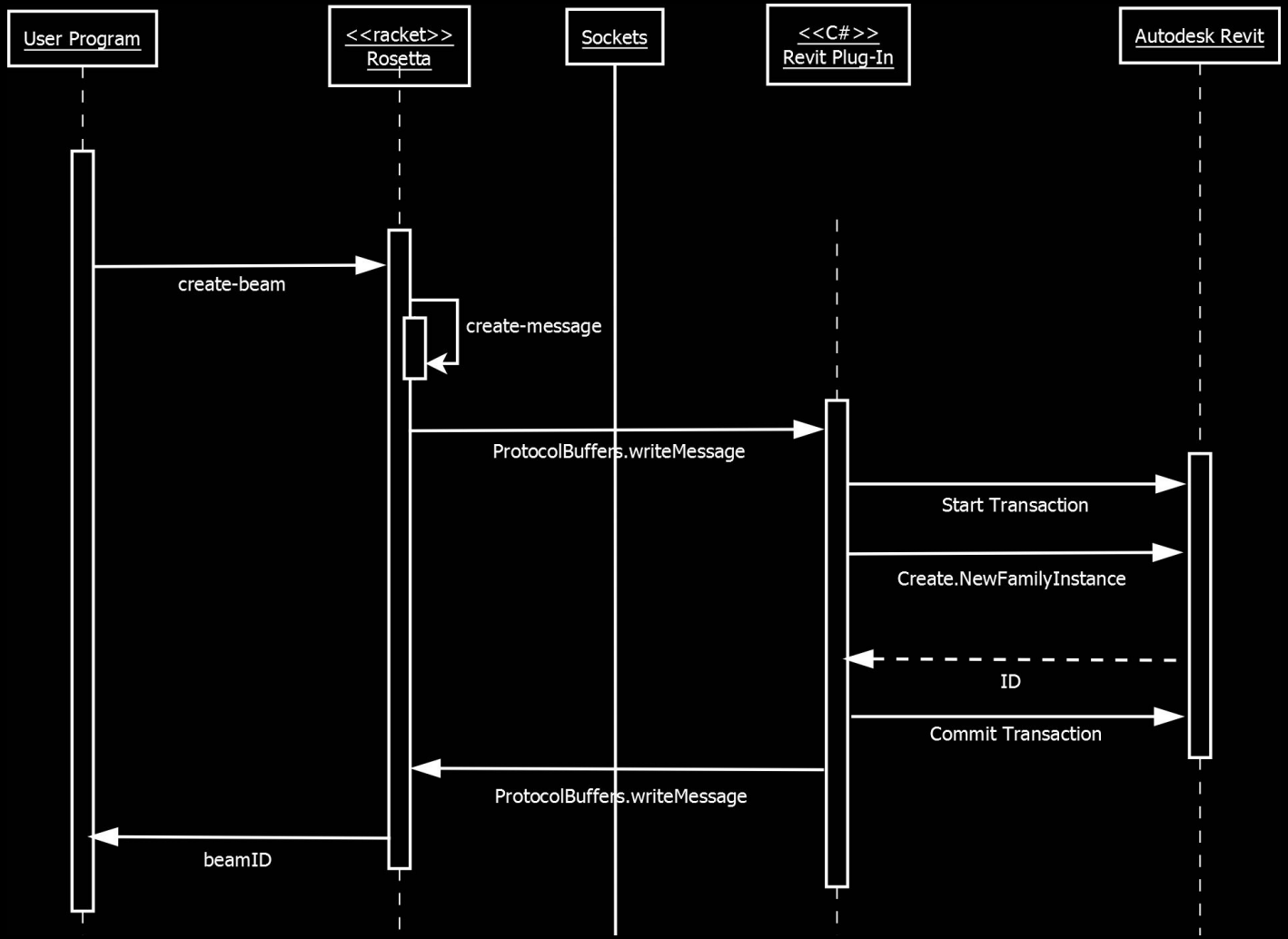
Abstraction Layer

```
(curtain-wall p0
              p1
              horizontal-bars
              vertical-bars
              base-level
              top-level)
```



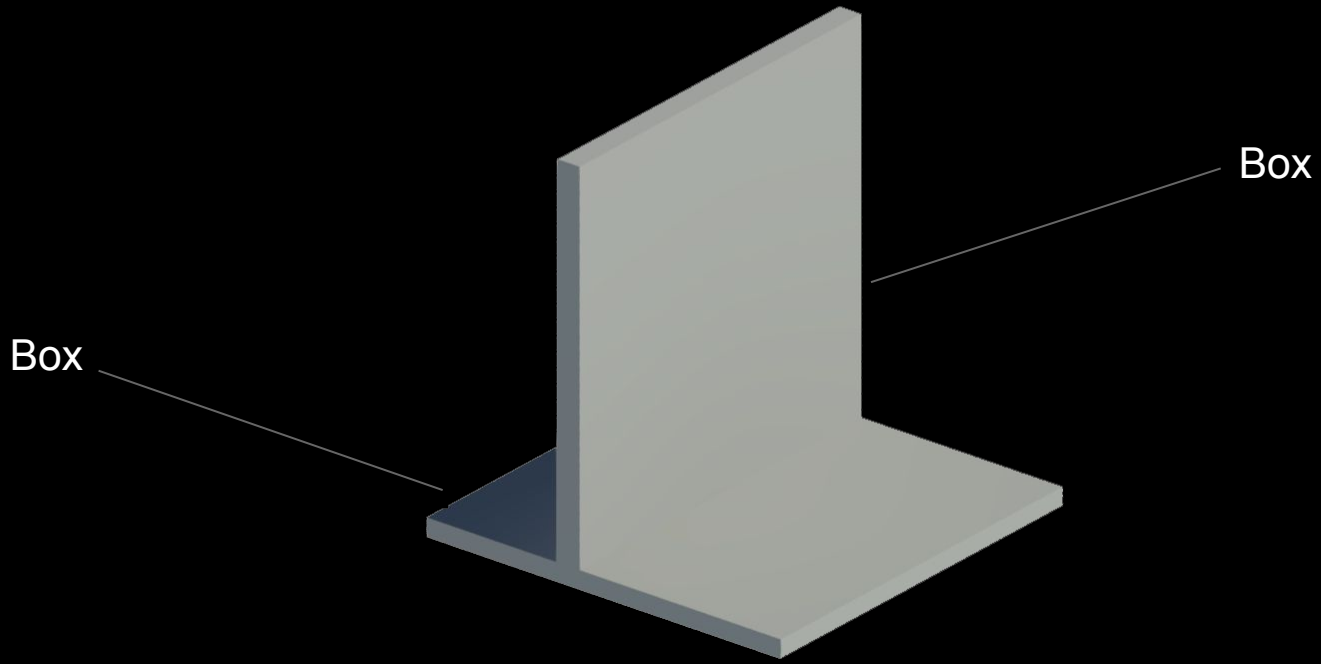
Abstraction Layer

```
(create-stairs-run base-level
                   top-level
                   p0
                   p1
                   width)
```


User Program
<<racket>>
Rosetta
Sockets
<<C#>>
Revit Plug-In
Autodesk Revit
create-beam
create-message
ProtocolBuffers.writeMessage
Start Transaction
Create.NewFamilyInstance
ID
Commit Transaction
ProtocolBuffers.writeMessage
beamID

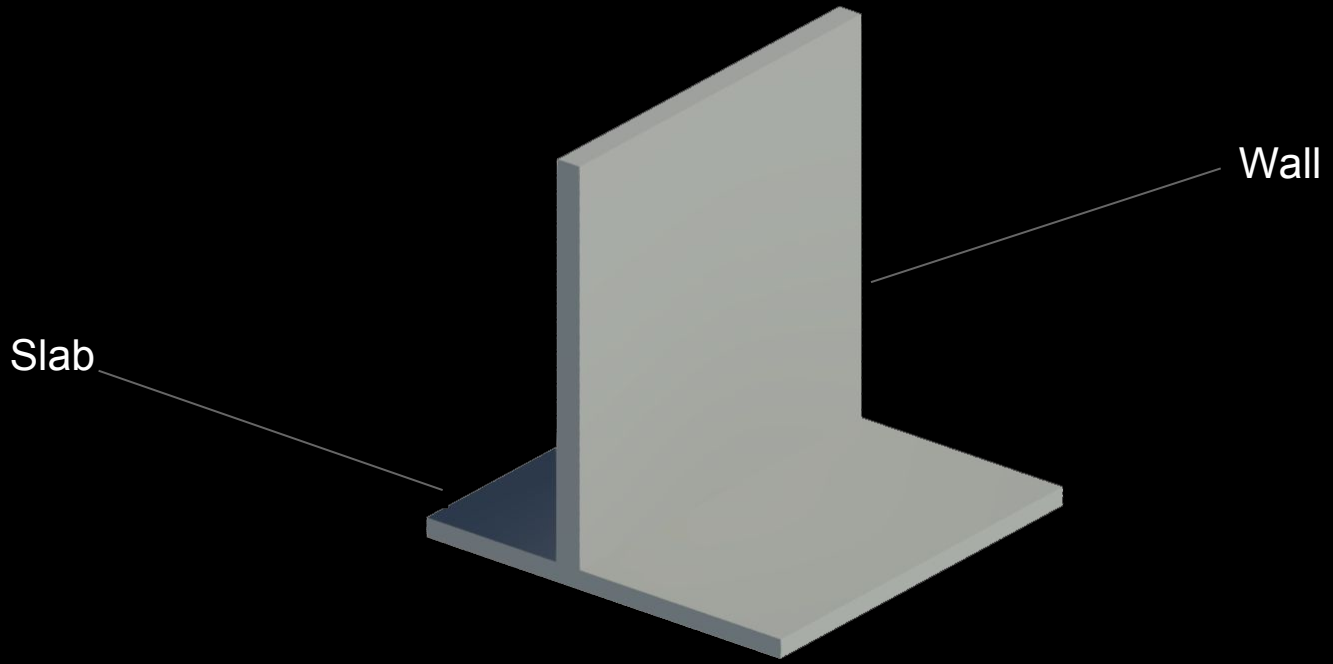
Programming for BIM

Semantics (CAD)




```
(box a b ...)
(box c d ...)
```

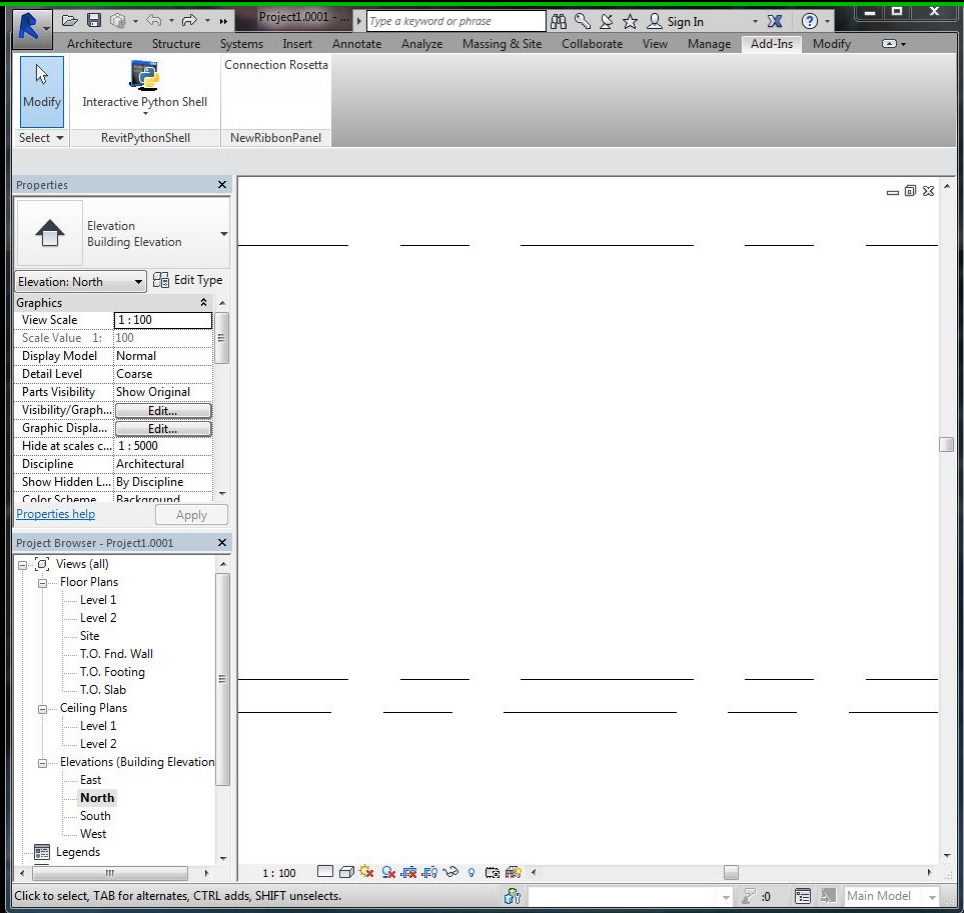
Semantics (BIM)




```
(wall a b ...)
(slab c d ...)
```

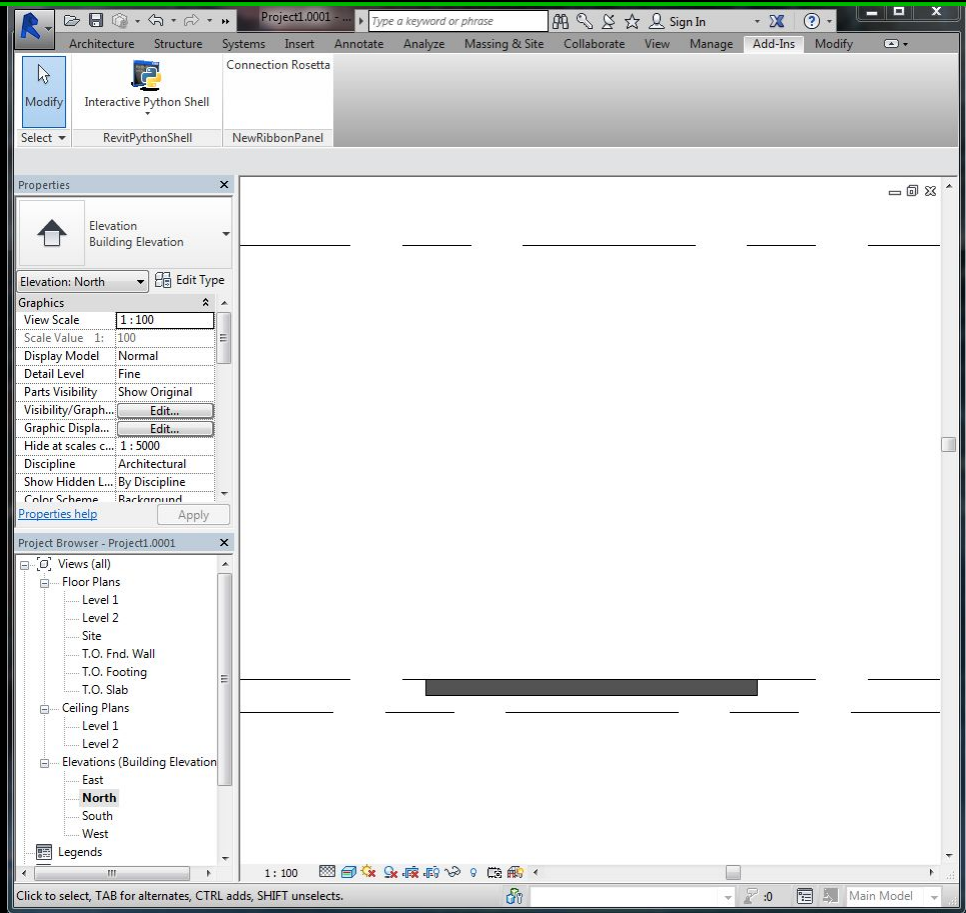
Dependencies

```
>(upper-level)
```



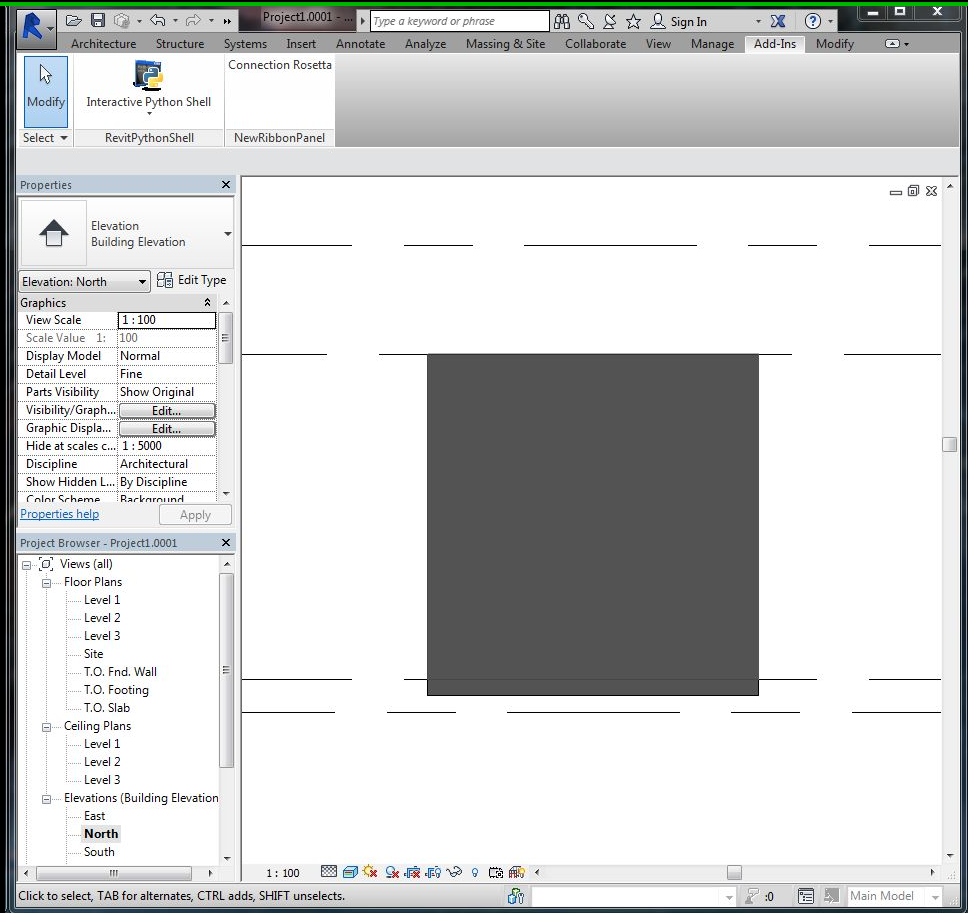
Dependencies

```
>(create-slab (list (u0)
                    (xyz 10 0 0)
                    (xyz 10 10 0)
                    (xyz 0 10 0)
                    (u0)))
```



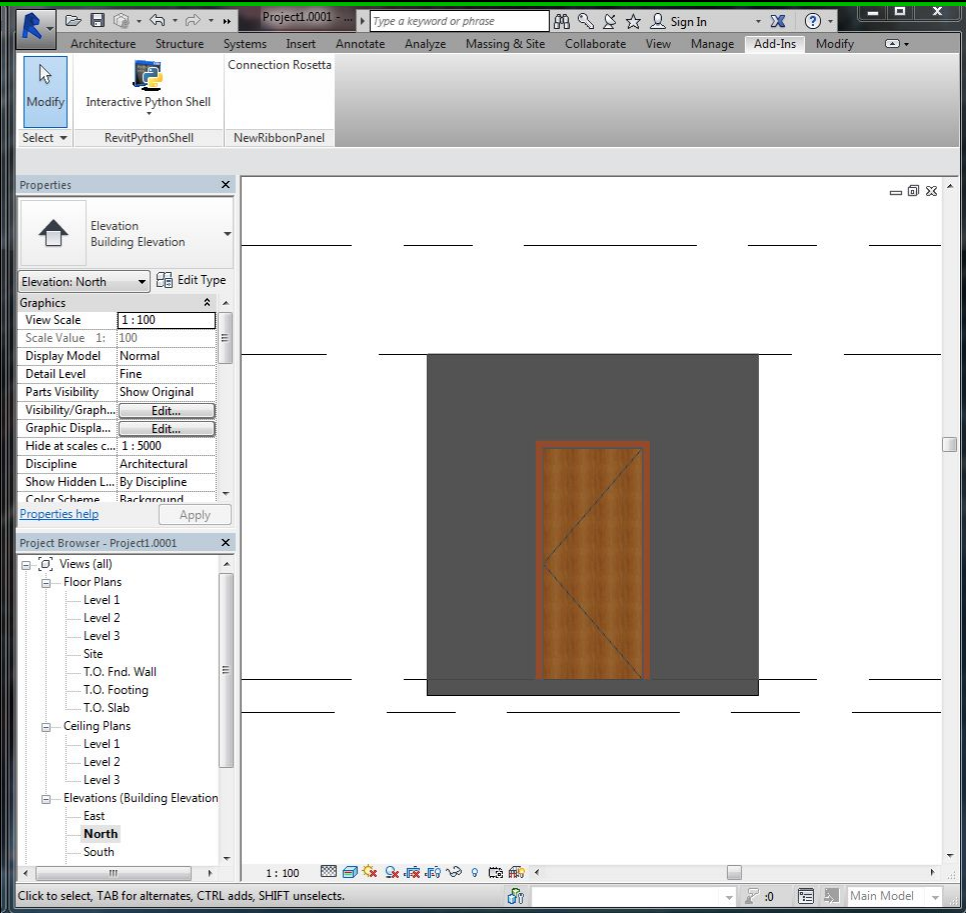
Dependencies

```
>(define w
   (create-wall
    (list (xyz 0 4 0)
          (xyz 10 4 0))))
```



Dependencies

```
>(insert-door (car w) (xyz 5 4 0))
```



Simplification

beamTest.rkt - DrRacket

File Edit View Language Racket Insert Tabs Help

beamTest.rkt (define ...) Debug Check Syntax Macro Stepper Run Stop

```
1  #lang racket
8  (define beam-family-1 (load-family "C:\\ProgramData\\Autodesk\
9
10 (define beam-family-2 (load-family "C:\\ProgramData\\Autodesk\
11
12 (define beam-family-3 (load-family "C:\\ProgramData\\Autodesk\
13
14
15 (define beam-family-element-1
16   (family-element  beam-family-1))
17
18 (define beam-family-element-2
19   (family-element  beam-family-2))
20
21 (define beam-family-element-3
22   (family-element beam-family-3))
23
24 (create-beam (xyz 0 0 0)
25              (xyz 0 10 0))
26
27 (create-beam (xyz 5 0 0)
28              (xyz 5 10 0)
29             #:family beam-family-element-1)
```

```
(idstrc '#hasheqv() #"" 266712)
(idstrc '#hasheqv() #"" 266719)
(idstrc '#hasheqv() #"" 266806)
>
```

Determine language from source 8:2 623.56 MB

Project1.0001 - ... Type a keyword or phrase Sign In

Architecture Structure Systems Insert Annotate Analyze Massing & Site Collaborate View Manage Add-Ins Modify

Modify Select | View Templates | Render | Render in Cloud | Render Gallery | Graphics | 3D View | Section | Callout | Create | Sheet Composition | Switch Windows | Close Hidden | User Interface | Windows

Properties

3D View

3D View: {3D} Edit Type

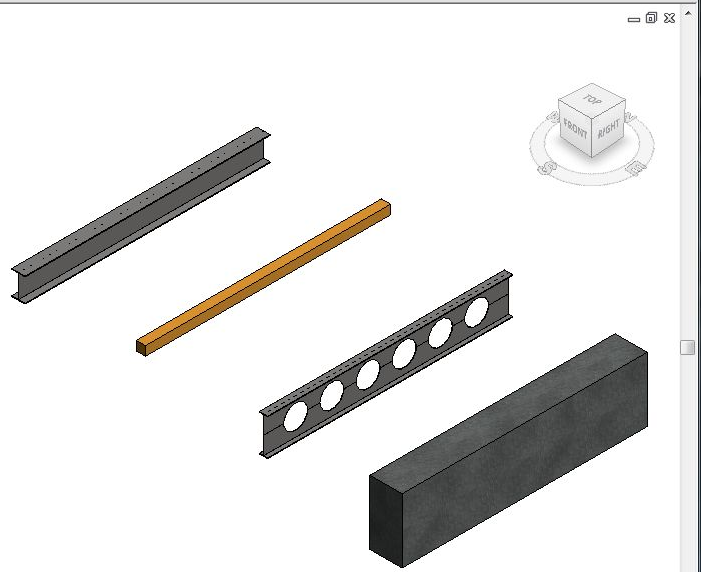
Graphics

View Scale	1 : 100
Scale Value 1:	100
Detail Level	Medium
Parts Visibility	Show Original
Visibility/Graph...	Edit...
Graphic Displa...	Edit...
Discipline	Coordination
Show Hidden L...	By Discipline
Default Analysi...	None
Sun Path	

Properties help Apply

Project Browser - Project1.0001

- Views (all)
  - Floor Plans
    - Level 1
    - Site
    - T.O. Fnd. Wall
    - T.O. Footing
    - T.O. Slab
  - Ceiling Plans
    - Level 1
  - 3D Views
  - Elevations (Building Elevation)
    - East
    - North
    - South
    - West
- Legends
- Schedules/Quantities



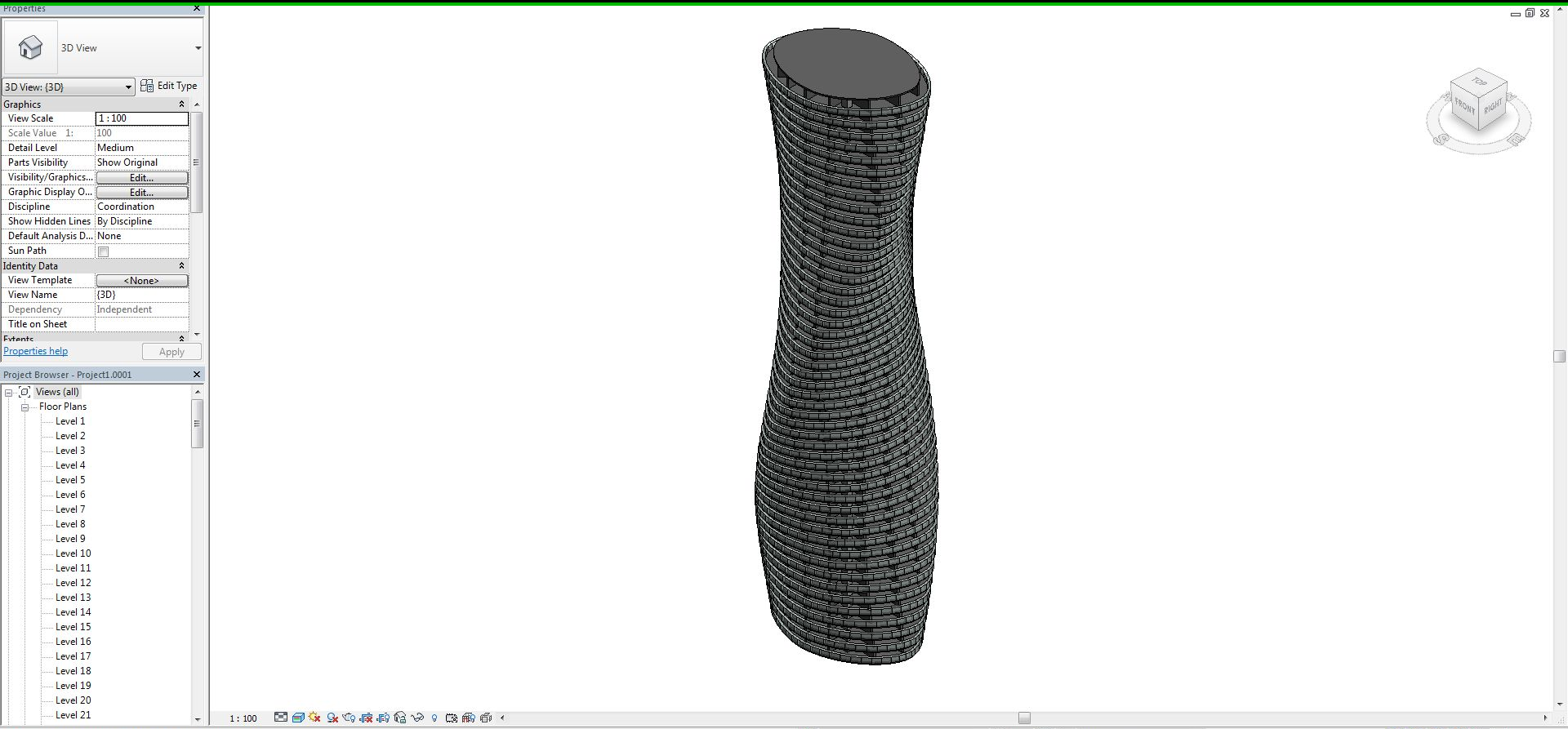
1 : 100

Click to select, TAB for alternates, CTRL adds, SHIFT unselects. Main Model

Evaluation

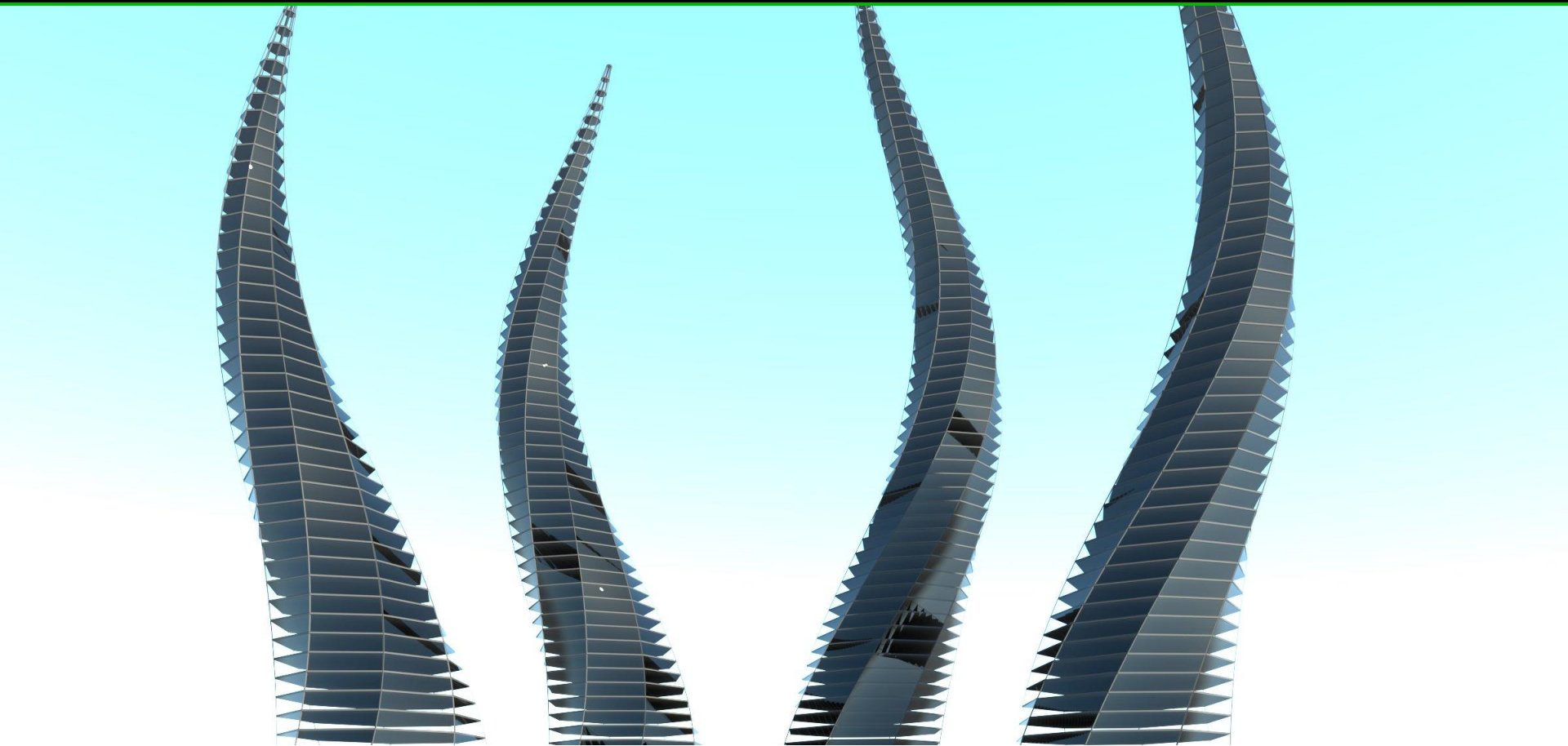
Absolute Towers

Absolute Towers



Absolute Towers

Dubai Towers



Simplification

Random Door.rkt - DrRacket

File Edit View Language Racket Insert Tabs Help

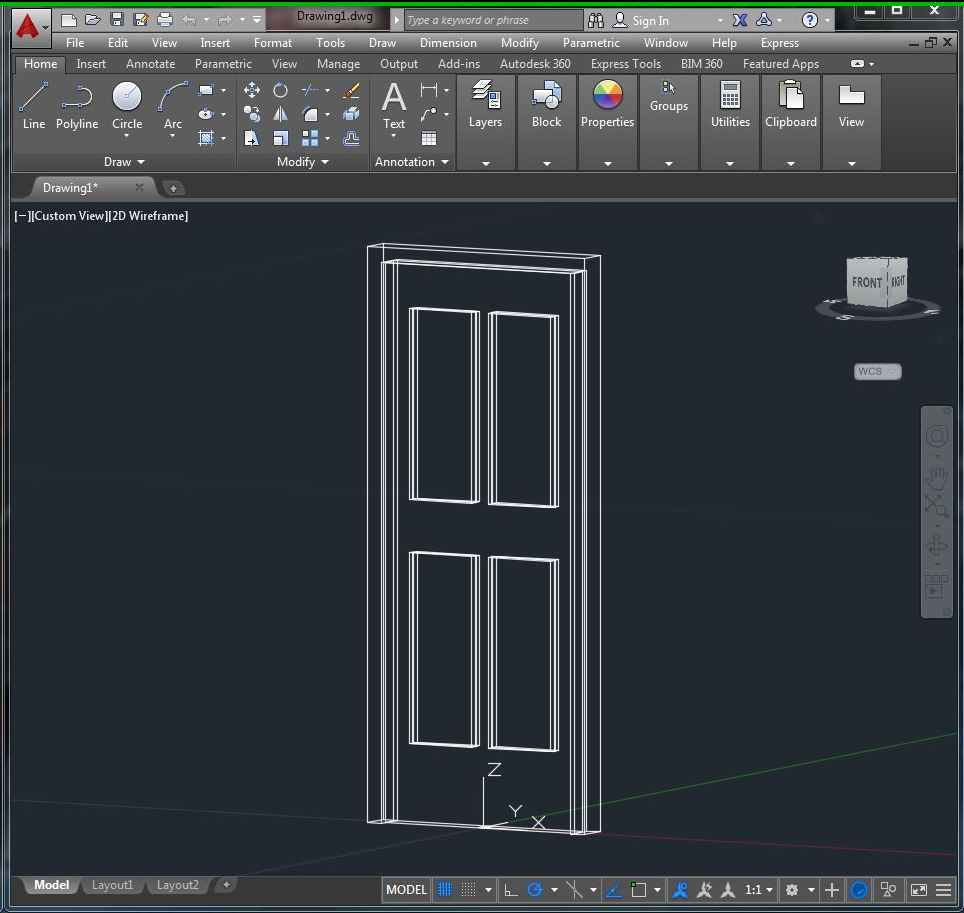
Random Door.rkt (define ...) Debug Check Syntax Macro Stepper Run Stop

```
1  #lang racket
4
5  (define (casing p L l h)
6    (define casing-lenght 0.06)
7    (define casing-width 0.12)
8    (sweep (line (+x p (- (/ L -2) (/ casing-lenght 2)))
9                 (+xz p (- (/ L -2) (/ casing-lenght 2)) (+ h (
10                (+xz p (+ (/ L +2) (/ casing-lenght 2)) (+ h (
11                (+x p (+ (/ L +2) (/ casing-lenght 2))))
12           (surface-rectangle p casing-lenght casing-width)))
13
14 (define (door p L l h)
15   (box (+xy p (/ L -2) (/ l -2)) L l h))
16
17 (define (glass p L l1 h)
18   (define door-margin-sides 0.1)
19   (define door-margin-up 0.17)
20   (define door-margin-bottom 0.3)
21   (define door-middle-horizontal 0.2)
22   (define door-middle-vertical 0.07)
23   (define n-glasses-horizontal 2)
24   (define n-glasses-vertical 2)
25   (define glass-area-length (- L
```

Language: racket; memory limit: 128 MB.

```
Starting AutoCAD...
'((#<box 12> #<box 13>) (#<box 14> #<box 15>))
>
```

Determine language from source 1:0 754.95 MB



Simplification

strangeTest4.rkt - DrRacket*

File Edit View Language Racket Insert Tabs Help

strangeTest4.rkt (define ...) Debug Check Syntax Macro Stepper Run Stop

```
1  #lang racket
2  (require rosetta/revit)
3
4  (define door-family
5    (load-family "C:\\ProgramData\\Autodesk\\RVT 2015\\Libraries
6
7  (define door-default-family-element
8    (family-element door-family))
9
10 (define w1
11   (create-wall (list (u0) (xyz (mt 10) 0 0))))
12
13 (insert-door-relative (car w1)
14                       (mt 5)
15                       0
16                       #:family door-default-family-element)
17
```

Language: racket; memory limit: 128 MB.

```
9
(idstrc '#hasheqv() #"" 263950)
>
```

Determine language from source 3:26 500.66 MB

Project1.0001 - ... Type a keyword or phrase Sign In

Architecture Structure Systems Insert Annotate Analyze Massing & Site Collaborate View Manage Add-Ins Modify

Modify Select | View Templates | Render | Render in Cloud | Render Gallery | Graphics | 3D View | Section | Callout | Create | Switch Windows | Close Hidden | Sheet Composition | User Interface | Windows

Properties

3D View

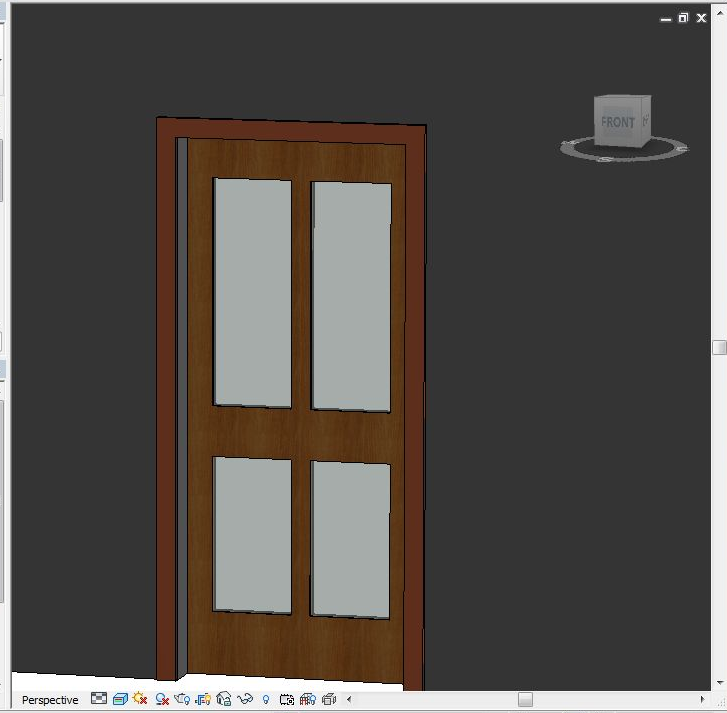
3D View: 3D View 1 Edit Type

Graphics	
Detail Level	Medium
Parts Visibility	Show Original
Visibility/Graph...	Edit...
Graphic Displa...	Edit...
Discipline	Architectural
Default Analysi...	None
Sun Path	
Identity Data	
View Template	<None>
View Name	3D View 1
Dependency	Independent

Properties help Apply

Project Browser - Project1.0001

- Views (all)
  - Floor Plans
    - Level 1
    - Level 2
    - Site
    - T.O. Fnd. Wall
    - T.O. Footing
    - T.O. Slab
  - Ceiling Plans
    - Level 1
    - Level 2
  - 3D Views
  - Elevations (Building Elevation
    - East
    - North
    - South
    - West



Perspective

Ready :0 Main Model

Scripting

PythonTest.rkt - DrRacket

File Edit View Language Racket Insert Tabs Help

PythonTest.rkt (define ...) Debug Check Syntax Macro Stepper Run Stop

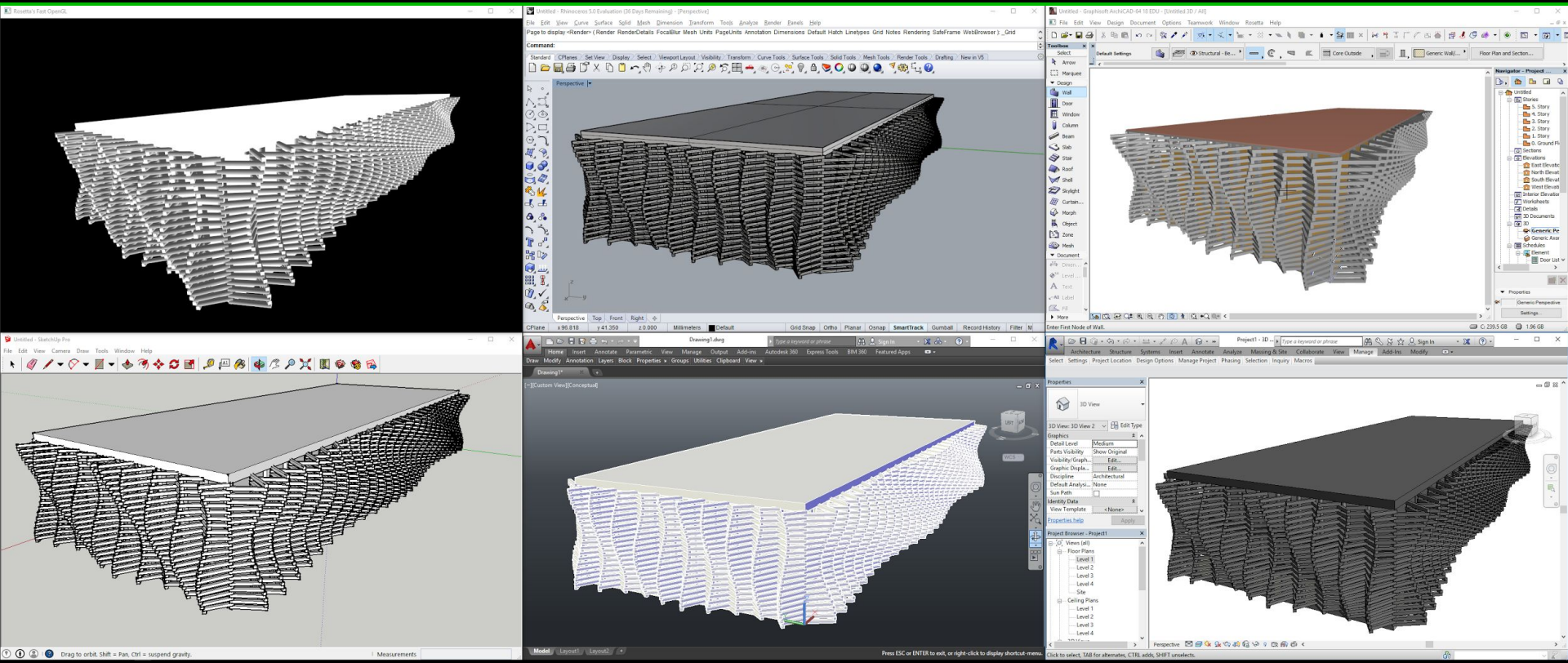
```
1 #lang python
2
3 from 'rosetta/revit' import *
4
5 for i in range(30):
6   for j in range(30):
7     box(xy(i*11, j*11), 10, 10, 10)
```

rpsExample.py - C:\Users\BrunoF\Documents\IST\Python\rpsExample.py (2.7.9)

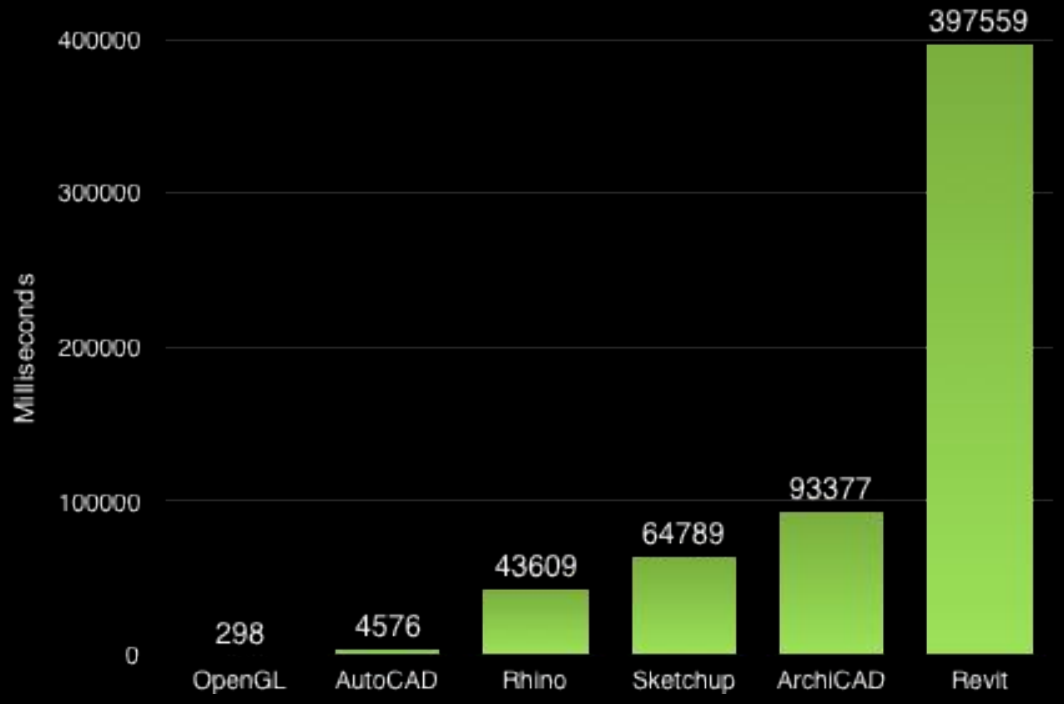
File Edit Format Run Options Windows Help

```
doc = __revit__.ActiveUIDocument.Document
app = __revit__.Application

t = Transaction(doc, 'Create extrusion.')

t.Start()

start_time = time.time()

#Create a sketch plane
origin = XYZ.Zero
normal = XYZ.BasisZ

plane = Plane(normal, origin)
skplane = SketchPlane.Create(doc, plane)

for i in range (0, 30):
        for j in range(0, 30):
                #Create line vertices
                lnPt1 = XYZ(0 + i * 11,0 + j * 11,0)
                lnPt2 = XYZ(10 + i * 11,0 + j * 11,0)
                lnPt3 = XYZ(10 + i * 11,10 + j * 11,0)
                lnPt4 = XYZ(0 + i * 11,10 + j * 11,0)

                #create lines
                lineA = Line.CreateBound(lnPt1, lnPt2)
                lineB = Line.CreateBound(lnPt2, lnPt3)
                lineC = Line.CreateBound(lnPt3, lnPt4)
                lineD = Line.CreateBound(lnPt4, lnPt1)

                #create model curves from lines
```

Portability



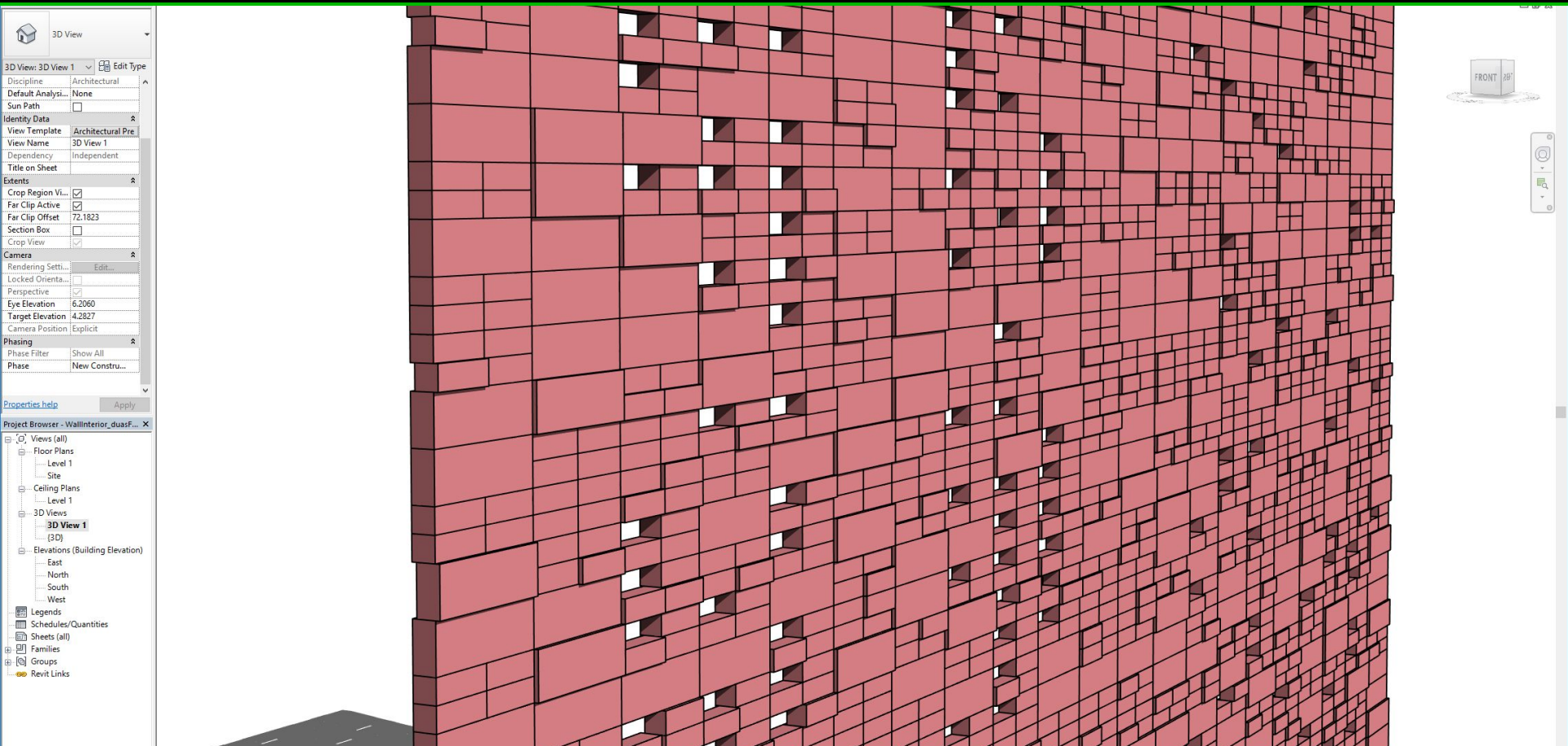
Performance



Performance

Task	Manual	Programmed
Model Production	2h 14min	14h
Change slab shape	1h 25min	10min
Increase number of floors	48min	7min
Increase slab size	1h 52min	4min

Real Case Application



Future Work

- More BIM back-ends
- More operations
- Tool interoperability

Contributions

- B. Ferreira and A. Leitão, “Generative Design for Building Information Modeling”, in *Real Time - Proceedings of the 33rd International Conference on Education and Research in Computer Aided Architectural Design in Europe, Vienna, Austria,* 2015, pp. 635-644

- S. Feist, G. Barreto, B. Ferreira, and A. Leitão, “Portable Generative Design for Building Information Modelling”, in *Living System and Micro-Utopias: Towards Continuous Design - Proceedings of the 21st International Conference of the Association for Computer-Aided Architectural Design Research in Asia, Melbourne, Australia,* 2016, pp. 147-156

TÉCNICO LISBOA

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Thank you!

Questions?