From 2D Architectural Drawings to 3D Models in a CAD Environment

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Introduction

This workshop series aims to provide an overview of 3d modeling techniques for real-time visualization. The workshops seek to provide an overview of the best practices in 3D modeling aimed to produce detailed, clean, and light models for real-time visualization. Topics covered in the workshops range from manual (parametric) to automated and procedural modeling. Attendees will also learn how to import their optimized 3D models in Unity game engine and build an interactive walk-through application for the Virtual Reality headset Oculus Rift. Theoretical concepts will also be provided throughout the tutorial along with hands-on activities.

Software and material

Parametric modeling

- **SketchUp** (Download free version: http://www.sketchup.com/products/sketchup-pro)
- **AutoCAD** (Educational license: http://www.autodesk.com/education/free-software/all)

Polygonal modeling

- **Blender** (Download: https://www.blender.org/)
- **3ds Max** (Educational license: http://www.autodesk.com/education/free-software/all)

Download tutorial material from: https://duke.box.com/v/3D-WS1

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Basics of 3D modeling

The creation of 3D models and sceneries is enabled by a large number of software and platforms specialized in specific tasks or domains. None of the software currently available is able to manage the entire 3D workflow from the design and creation to the 3D real-time visualization.

Computer Graphics (CG) representation is based on two main categories: vector representation and discrete representation, the first being a mathematical (parametric) description of an object, and the latter being a segmented approximation of it (Figure 1).

A **Polygonal Mesh** (mesh) is a discrete approximation of a continuous surface. Similarly to 2D raster images, meshes are resolution dependent. This means that they cannot be scaled up without significant loss of graphic detail. To overcome this issue, complex objects in a real-time engine can be represented using different instances at different resolution called Levels of Detail (**LODs**). The least detailed LOD is meant to be seen from a distant point of view, the most detailed one at close range. The LOD technique is used to increase the efficiency of rendering by decreasing the workload on the Graphic Processing Unit.

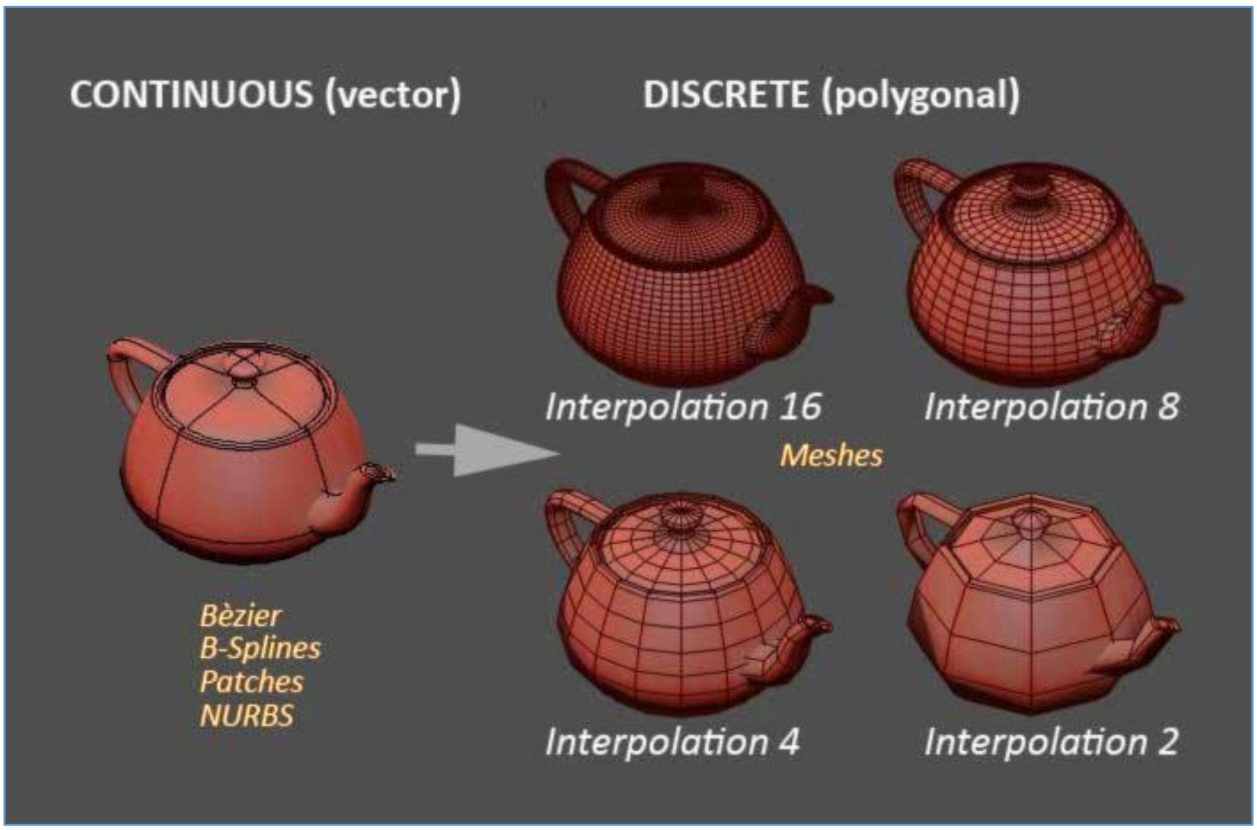


Figure 1: Continuous vs. discrete geometry in 3ds Max.

Preserving graphic details and realism in a Virtual Reality environment is a major challenge that video game artists are constantly facing. Polygonal models need to be very simple in order to minimize the workload on the Graphic Processor Unit. To overcome this issue, different techniques borrowed from computer game design can be used to increase the efficiency of real-time rendering.

3D models can be generated as follows: **manual modeling** (parametric) in a CAD environment (e.g. Autodesk AutoCAD) or 3D modeling software (e.g. Blender, Autodesk 3D Studio Max, etc.); **automatic generation** from laser-scanned data or image-based modeling (e.g. Agisoft PhotoScan); **procedural generation** via dedicated software (e.g. ESRI CityEngine).

Manual modeling

Manual modeling encompasses a wide range of techniques, such as box modeling, digital sculpting, and parametric modeling. The latter involves the use of **geometric primitives** (simplest geometric object such as cube, sphere, cylinder, etc.) along with **Constructive Solid Geometry techniques** (CSG). CSG entails the usage of **Boolean operations** (e.g. union, subtraction, and intersection), **shape extrusion along a path**, and **rotation of a profile about an axis**.

A best practice of manual modeling implies the usage of digitized architectural drawings (preferably blueprints) that are imported into a CAD program and then scaled to fit the local system unit. This last operation is meant to provide an accurate support for retracing profiles and contours that can be used in 3D model generation. As an alternative to manual modeling from scratch, one can import and modify existing models made by others or download from the internet (e.g. Trimble Warehouse, www.123dapp.com or www.sketchfab.com) but usually they cannot provide the necessary quality needed for a good project.

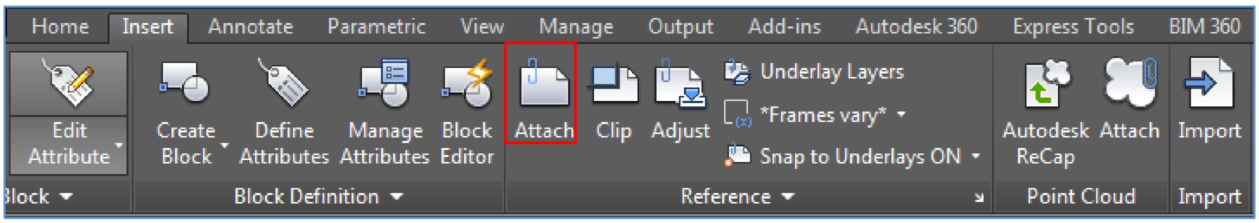
Preserving a parametric version of an object (matrix) allows the generation of an unlimited number of discretized instances at different steps of interpolation (mesh resolution) depending on the need. Conversely, discretized meshes cannot be easily reverted to a parametric object unless you use complex reverse engineering techniques.

Figure 2: Photorealistic reconstruction of a Roman forum built in Unity.

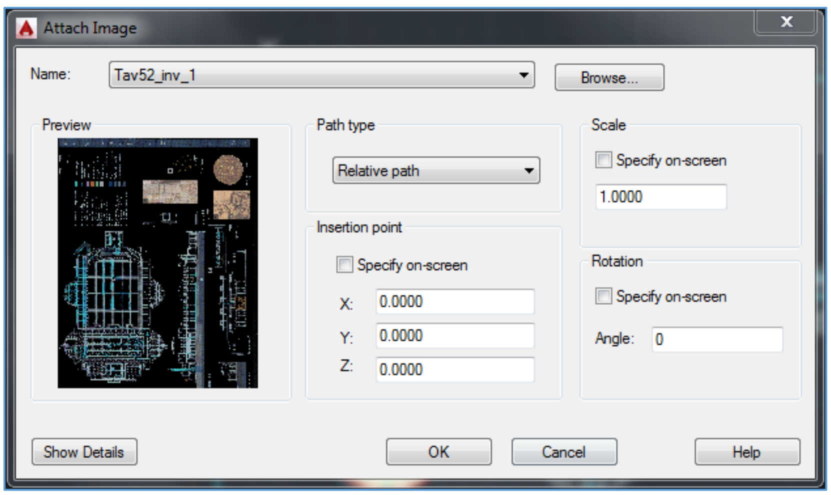
Tutorial 1: Architectural modeling in AutoCAD

This tutorial provides step-by-step instructions for the modeling of the Basilica Ulpia (Rome) in AutoCAD. Reference drawings in Figure 3 and Figure 4 have been modified in Photoshop to enhance the sharpness of the lines. The colors are inverted in order to make the lines contrast with AutoCAD viewport background.

1. Launch AutoCAD, select **Insert** tab in the Ribbon and click on **Attach** as shown below:



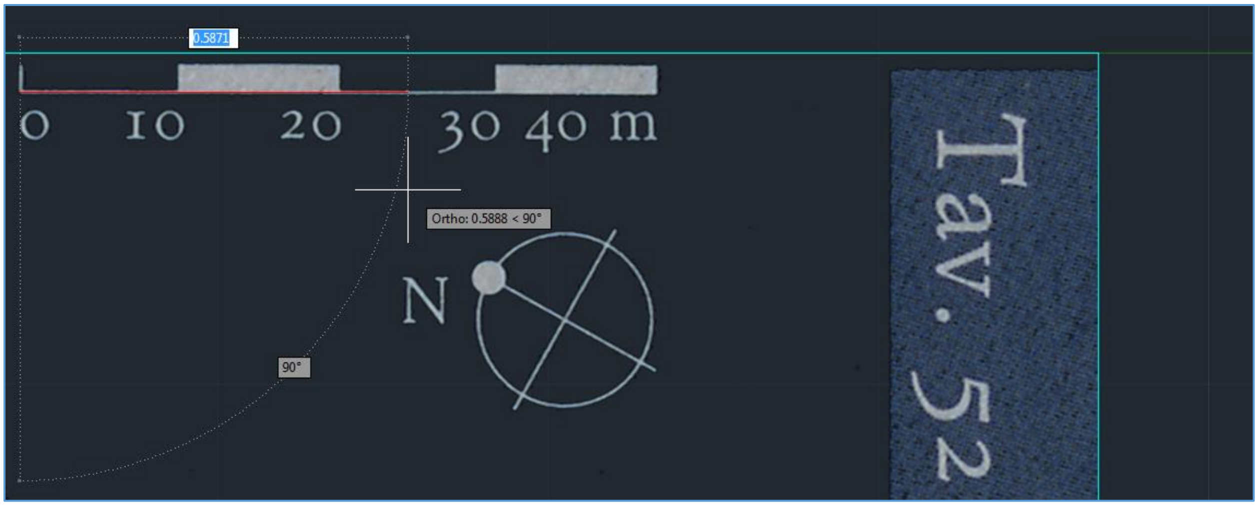
2. Browse to the **WIP** (Work In Progress) folder / **WS1_tut01** and select *Tav52_inv.tif*.
3. Set parameters in the window as shown below:



Uncheck "Specify on-screen" in the Insertion point, Scale and Rotation sections. **Note**: For setting the **relative path** you need to have first saved your file by clicking on (**Menu**) / **Save**.

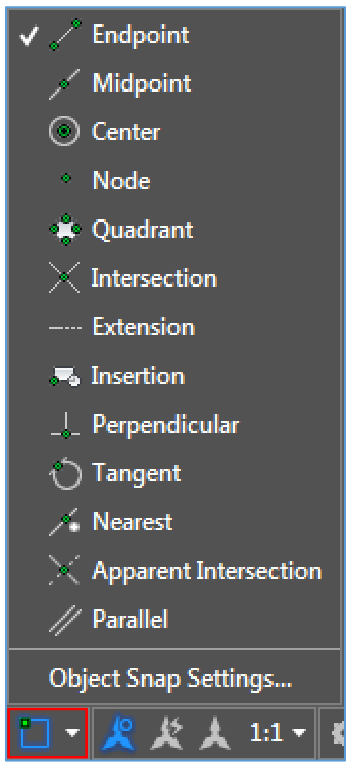
4. Right-click on the picture frame and select Properties. Set **Background transparency** to Yes.
5. Make sure that **ORTHOMODE** (F8) is active and **O**[bject]**SNAP** (F3) is disabled in the Status Bar, as shown below:

6. Locate the scale bar in the reference blueprint (roughly in the top-right corner) and zoom in using the mouse wheel. Alternatively, type "**Z**" and **Enter**, then draw a rectangular selection.
7. Type "**L**" and **Enter** to draw a line. Specify the first point by clicking on the beginning of the scale bar in correspondence of "0" as shown in the picture below. Move the mouse cursor rightward, type "**40**", and press **Enter** to specify the segment length. Then **Esc** to end the drawing command.



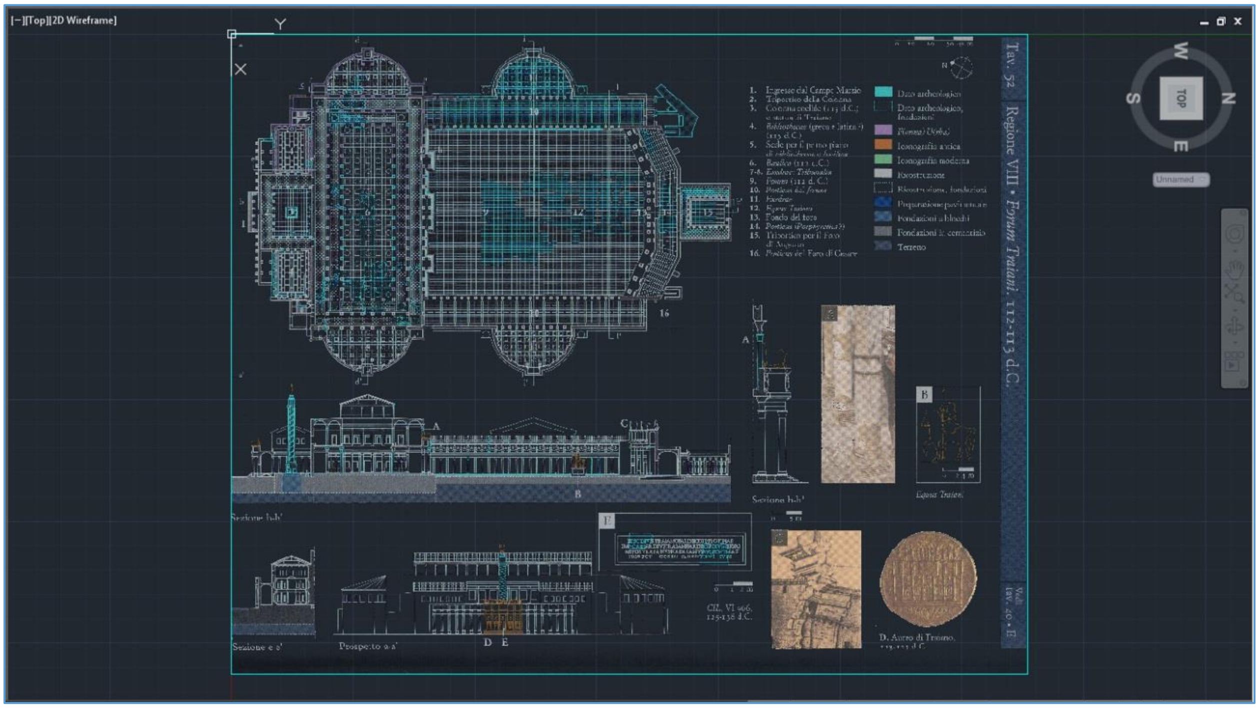
You should see now a line 40 m long. You need now to make the reference blueprint fit the system scale.

8. Make sure that **OSNAP** is active and **Endpoint** option is checked.

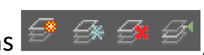


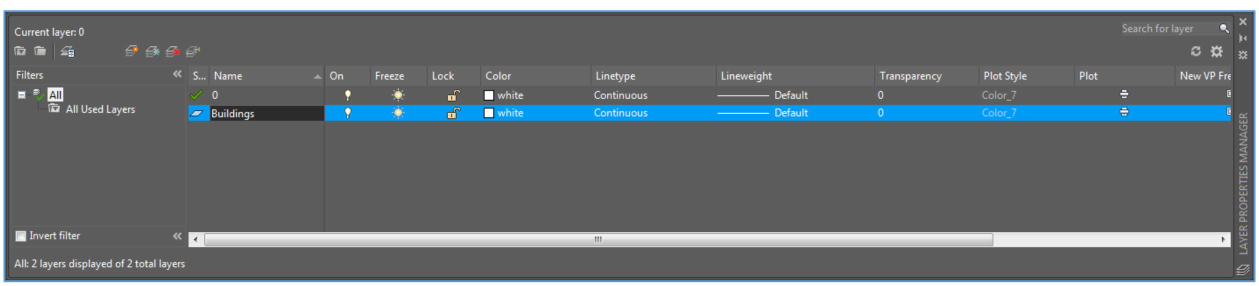
9. Type "**SC**" (Scale) and **Enter**, select the blueprint frame and press **Enter** to confirm your selection.
10. Specify the base point for the transformation by snapping to the first point of the line. Then type "**R**" (Reference mode) and **Enter**, and then select again the first point of the line.
11. Deactivate **OSNAP** and specify the second point by clicking on the ending point of the scale bar in correspondence of "40 m" as drawn in the blueprint.
12. Reactivate **OSNAP** and specify the new ending point by snapping to the last point of the line. You should see now the blueprint scale bar perfectly matching the line.

13. Type “**M**” (move) and **Enter**, select the blueprint frame and press **Enter** again. Move the image in an appropriate location in the positive quadrant of the Cartesian coordinate plane.

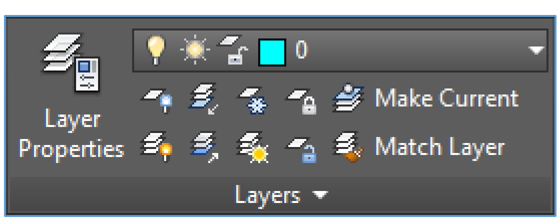


You are now ready for retracing the drawing using AutoCAD vector shapes.

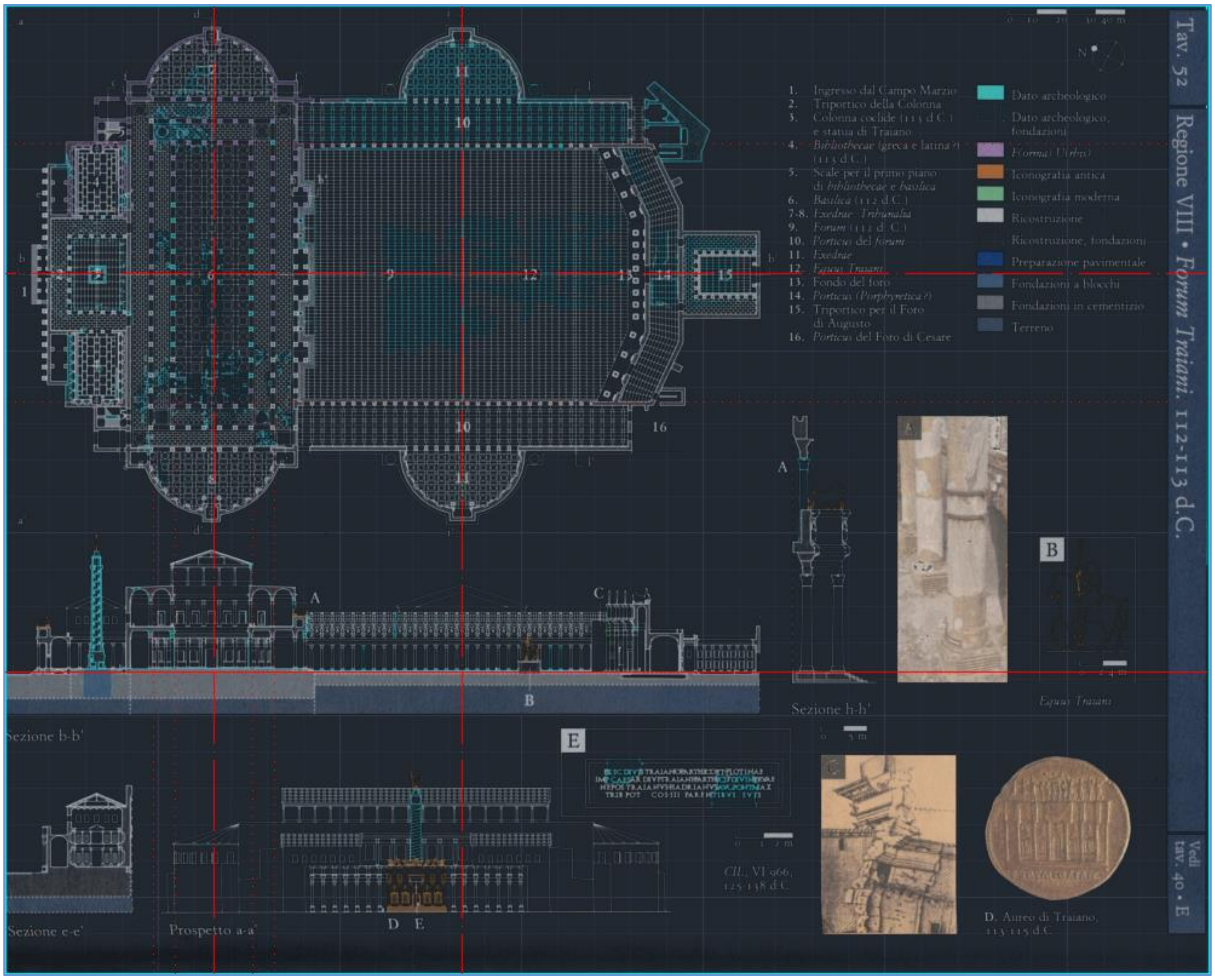
14. Type “**LA**” and **Enter** to open the Layers manager window, then create as many layers as necessary. You can add/remove layers by clicking on the relative buttons , show and hide layers clicking on the light bulb icon, and make a layer active (current) double-clicking on the status icon 



Remember that newly created objects will be assigned to the active layer. You can change the layer of an object using the layer tab in the ribbon:



15. Open **WIP** folder / **WS1_tut01** and double-click on **WS1_Tut1a.dwg**.



You should see the reference blueprint with some guides (symmetry axes and other reference lines).

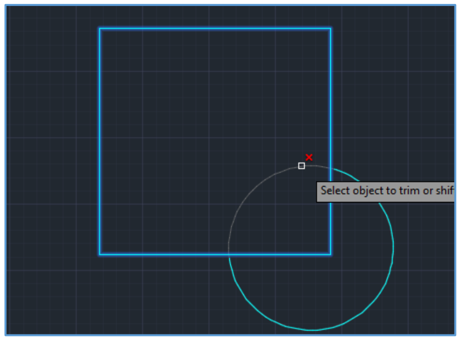
16. Make “Columns” layer active and start retracing the column bases using circular shapes. Type “**C**” and **Enter** in order to draw a circle, then specify the center and the radius length by clicking two points.
17. Type “**CP**” (Copy) and **Enter** to copy and paste shapes, then select the circle and **Enter** the selection. Specify as many points you want in order to clone your shape. You can activate ORTHOMODE or OSNAP to create a symmetrical layout.

There are many strategies to create a drawing suitable for 3d modeling. Every shape must be closed. Always use the OSNAP to correctly place your shapes in the proper location with the necessary accuracy. Try to make your drawing symmetrical and orthogonally oriented according to the X- and Y-axes. This will greatly simplify the 3d modeling process.

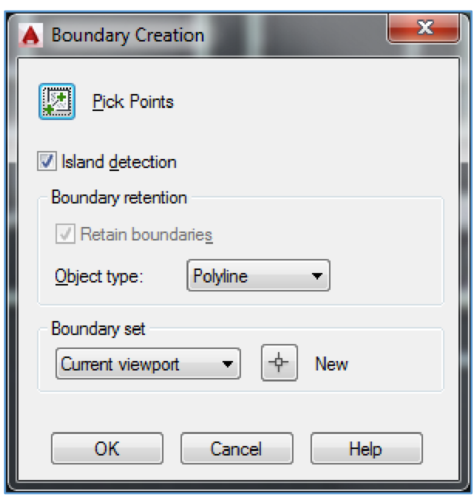
18. You can use different commands to create your shapes:

- Type “**L**” and **Enter** to create a line.
- Type “**C**” and **Enter** to create a circle.

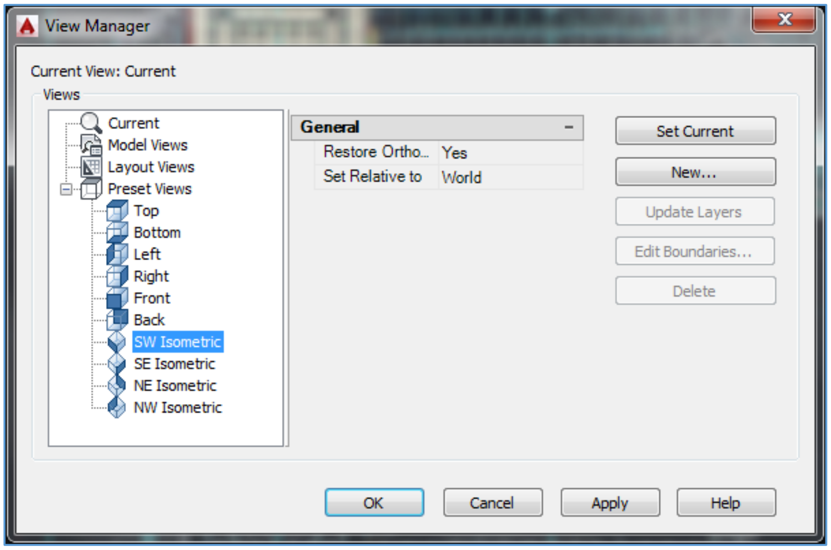
- Type "**PL**" and **Enter** to create a polyline. While drawing you can switch from Line-mode to Arc-mode by typing the subcommands "**L**" and "**A**" followed by **Enter**. While drawing in Arc-mode you can type the sub-subcommand "**D**" and **Enter** to give the arc a determined direction. Alternatively, you can adjust the arc direction later, manipulating the polyline grips.
- Type "**TR**" (Trim) and **Enter** to break a shape into smaller segments. Select first the cutting objects and **Enter** the selection, then click on the parts of the shapes that you want to delete as shown below. Press **Esc** when you are done.



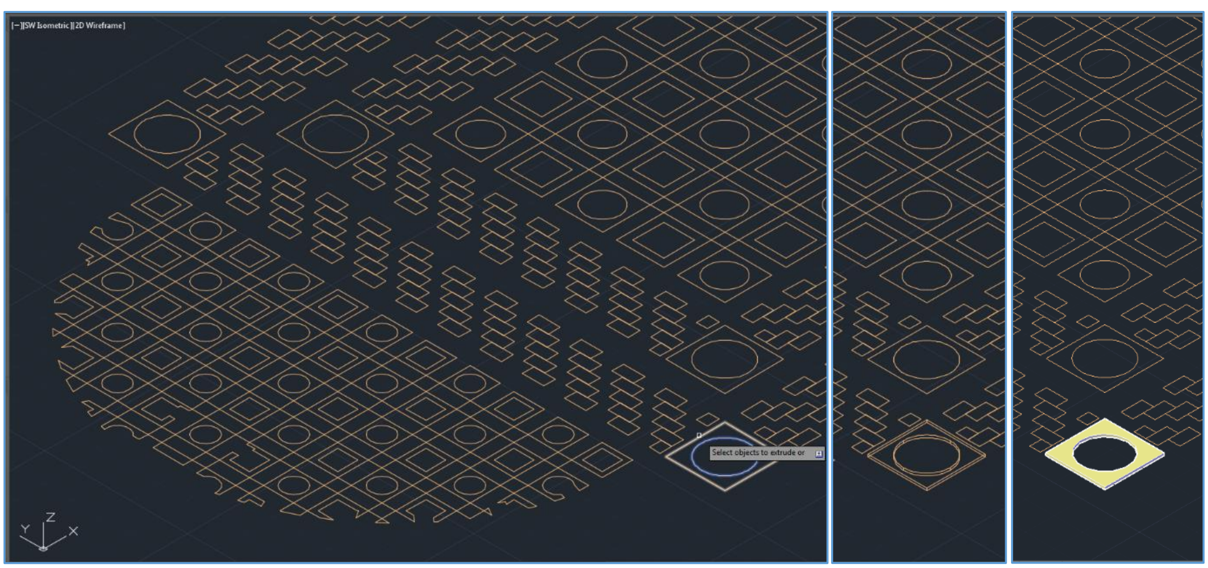
- Type "**EX**" (Extend) and **Enter** to complete a shape. First, select the objects that you wish to use as a boundary. The boundary is the object you want to extend an element to. Press **Enter** to confirm the selection and then click on the end of a line you want to extend. Press **Esc** when finished.
- You can edit a polyline typing "**PE**" and **Enter**, then type "**M**" (Multiple selection) and **Enter** to start selecting the shapes you want to edit. Confirm your selection with **Enter** and specify one of the following operations:
    - "**C**" and **Enter** to close the shape
    - "**J**" (**Join**) and **Enter** to merge all the selected objects into one shape. You may be asked to specify additional options before completing the command. Press **Esc** when done.
- Type "**BO**" (Boundary) and **Enter** to open the Boundary Creation window. Click on **Pick Points** and then specify points within each area to form a boundary polyline. **Note**: This area must be totally enclosed and there can be no gaps between enclosing objects.



19. Open **WIP** folder / **WS1_tut01** and double-click on **WS1_Tut1b.dwg** if you wish to get the job already done.
20. Time to go 3d! Type "**V**" (View) and **Enter** to show the views window. Expand the **Preset Views** dropdown list, double-click on one of the isometric views and press OK.



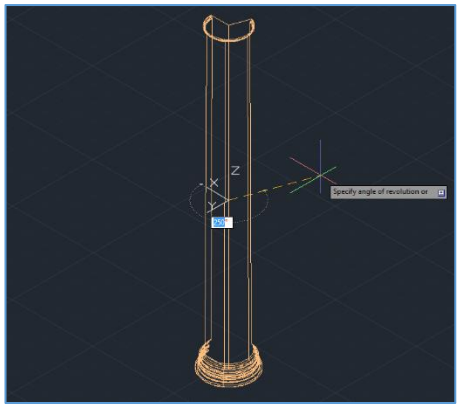
21. Hide all the layers different from "FloorRedMarb" and "Profiles". Make the first layer active.
22. Type "**EXT**" (Extrude) and **Enter**, then select two shapes as shown in the picture below. Confirm the selection with **Enter** and move the mouse cursor upward, over the shapes, then type "0.2" (the extrusion height) and **Enter** again. You will get two intersecting volumes.



23. Type "**VSM**" and **Enter** to show the **Visual Styles window**. Change from **2D Wireframe** to **Conceptual** shading in order to see the volumes.
24. Type "**SU**" and **Enter** to perform a **Boolean subtraction**. Select the solid to be subtracted from (the largest one) and confirm with **Enter**. Finally select the solid to subtract (the smallest one) and **Enter**

again. You should see the result as shown in the picture above. You can do multiple selections before entering but in this case, you will get a single bloc.

25. Type “**REV**” (Revolve) and **Enter**, then select the column profile and **Enter** again. Specify the starting and ending points of the column axis using the OSNAP tool set on Vertex. Move the mouse cursor around the axis in order to generate a 3d column or type “**360**” and **Enter** to get a full round solid.



26. You can retrace a profile relying on a background image properly aligned with your 3D geometry. Make the “RefDrawings” layer visible and set the view to **Left** using “**V**” command. Then make sure that the **User Coordinate System** is properly oriented with the current view. Type “**UCS**” and **Enter**, then type “**V**” (View) and **Enter** again. You can draw a polyline to retrace the profiles in the blueprints. If you revert to Isometric view, you will notice that the UCS is not correctly oriented. Use “UCS” command again, then type “**W**” (World) and **Enter** to reset the working plane horizontally.
27. You can extrude a closed profile along a path using the “EXT” command as usual but typing the subcommand “**P**” (Path) instead than entering an extrusion height, and picking a polyline as a path.

AutoCAD main command aliases list

3DO 3DORBIT

3R 3DROTATE

AR ARRAY

- **PA**TH
- **PO**LAR

B BLOCK

BO BOUNDARY

BR BREAK

C CIRCLE

CH PROPERTIES

CHA CHAMFER

- **D**ISTANCE

CO COPY

CP COPY

CYL CYLINDER

DI DIST

DIV DIVIDE

DT TEXT

E ERASE

EL ELLIPSE

EX EXTEND

EXT EXTRUDE

- **P**ATH

F FILLET

- **R**ADIUS

FI FILTER

H HATCH

HE HATCHEDIT

IN INTERSECT

J JOIN

L LINE

LA LAYER

M MOVE

MI MIRROR

O OFFSET

OS OSNAP

P PAN

PE PEDIT

- **M**ULTIPLE
  - **C**LOSE
  - **J**OIN

PL PLINE

- **A**RC
- **L**INE

PO POINT

PR PROPERTIES

PU PURGE

RE REGEN

REC RECTANG

REV REVOLVE

RO ROTATE

- **C**OPY
- **R**EFERENCE

SC SCALE

- **C**OPY
- **R**EFERENCE

SL SLICE

SU SUBTRACT

TR TRIM

UCS UCS

- **F**ACE
- **V**IEW
- **W**ORLD
- **X**
- **Y**
- **Z**

UN UNITS

UNI UNION

V VIEW

VSM VISUALSTYLES

X EXPLODE

Z ZOOM

- **A**LL
- **W**INDOW

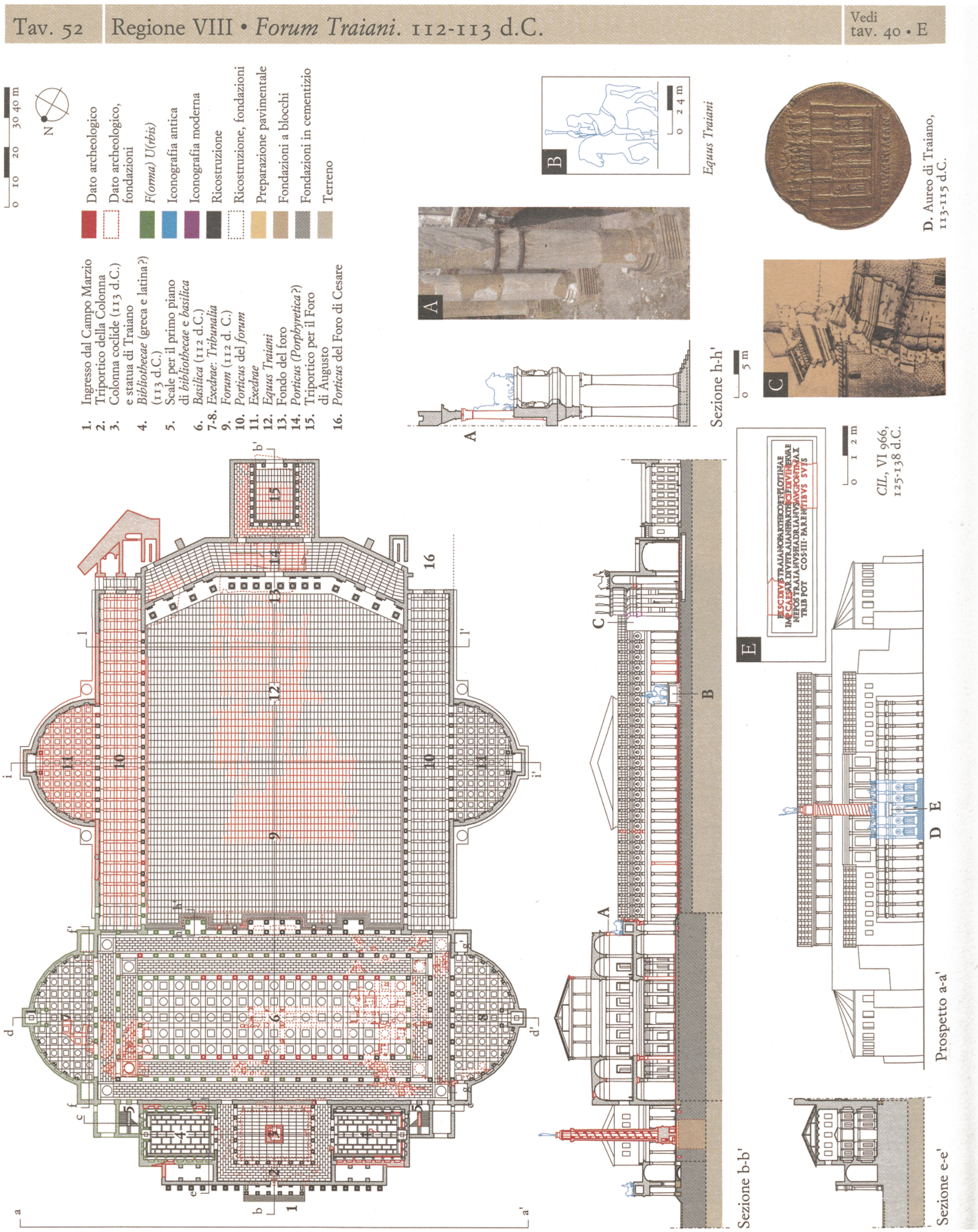


Figure 3: A. Carandini, Atlante di Roma Antica, Pl. 52.

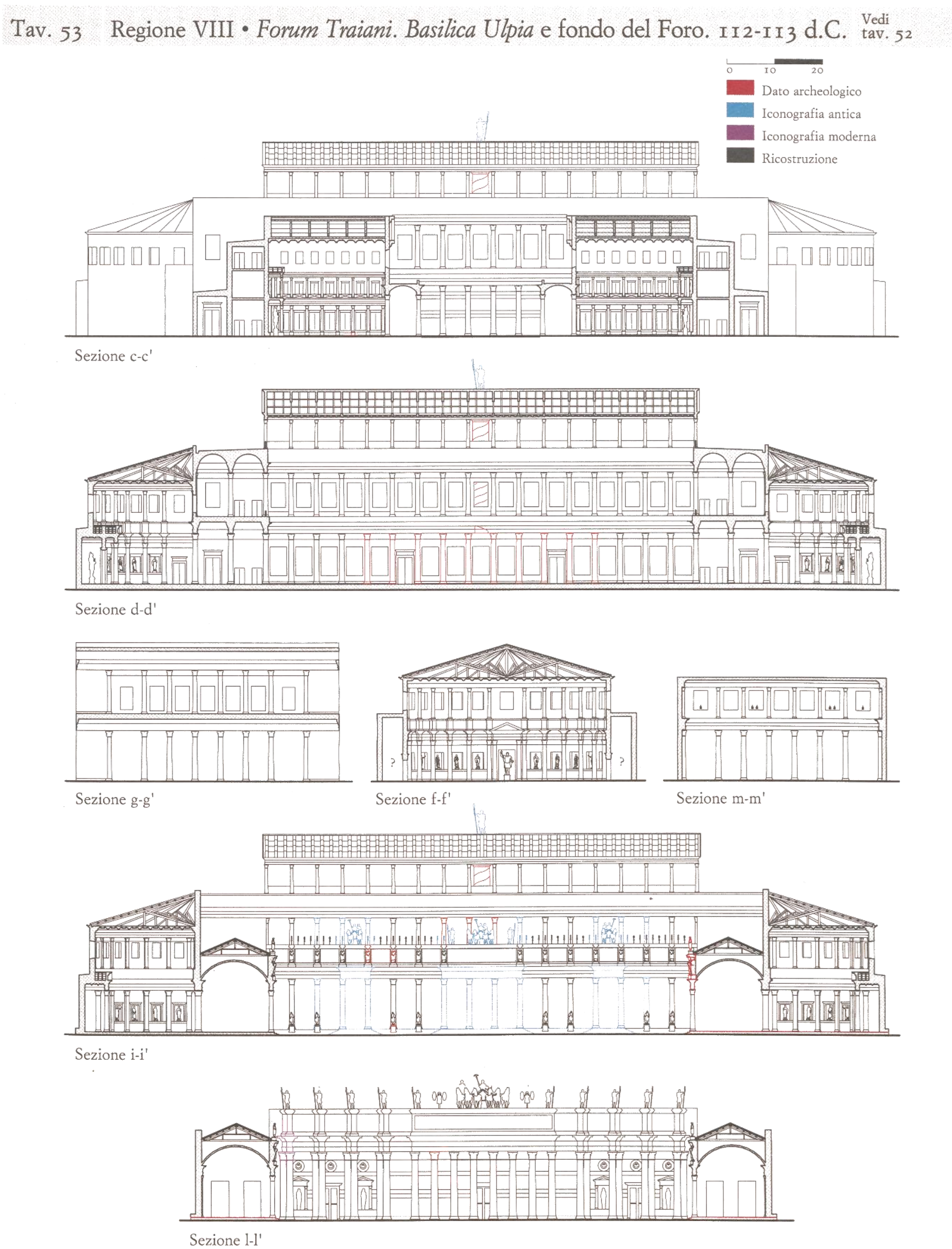
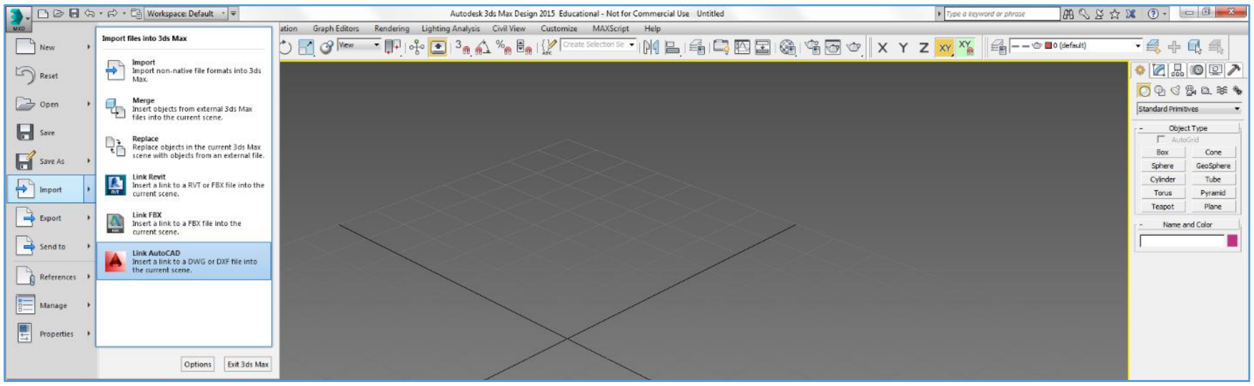


Figure 4: A. Carandini, Atlante di Roma Antica, Pl. 53.

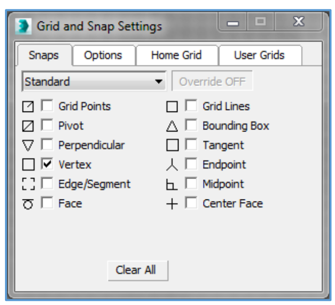
Tutorial 2: Modeling a Corinthian Column in 3ds Max

This tutorial provides step-by-step instructions for the modeling of a Corinthian column in 3ds Max. See Vignola's reference drawings (Figure 5 and Figure 6 or *RomanCorinthian.dwg*).

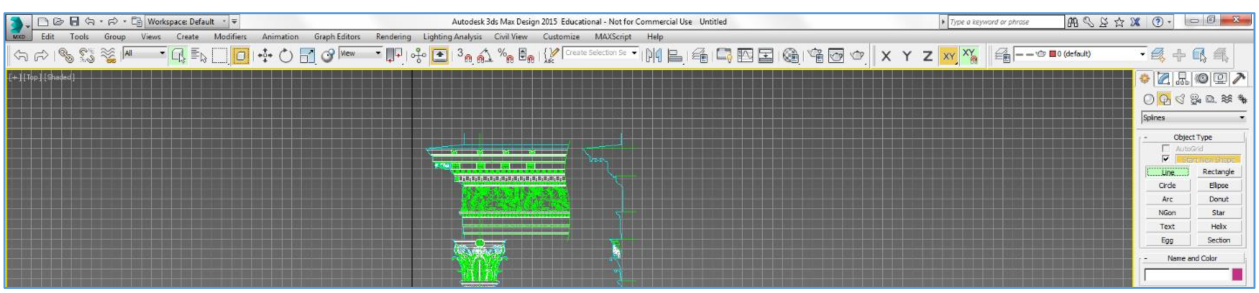
1. Launch 3ds Max, select (**Menu**) / **Import** / **Link AutoCAD** as shown below:



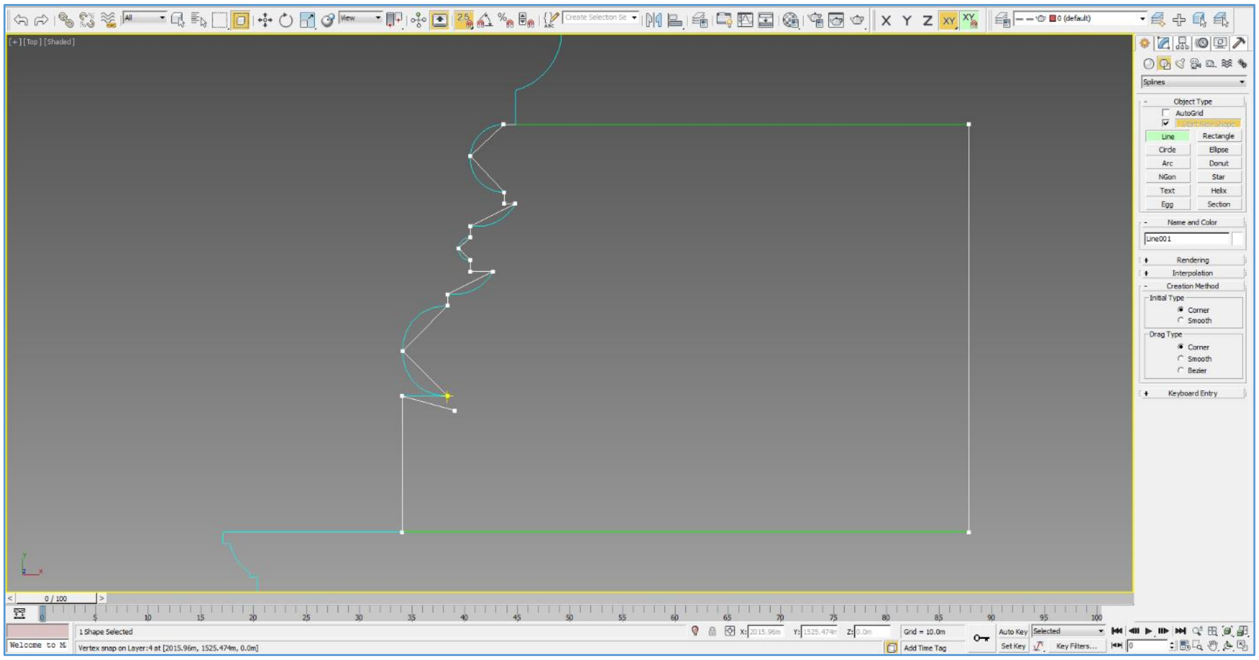
2. Browse to the **WIP** folder / **WS1_tut02** and select *RomanCorinthian.dwg*. Then **Attach this file**. You should see now the reference drawing appear in the viewport. Press "**T**" to switch to the Top View – or use (Maximize/Minimize View Toggle) in the lower right corner of the window – and "**Z**" to zoom fully.
3. On the main tool bar, click-and-hold the **Snaps Toggle** and select the (**2.5 Snap**) option. Then right click on the icon and check **Vertex** as shown below:



4. Go to the right **Command Panel** / **Create Tab** / (**Shapes**) / **Splines** and select Line command as shown below:

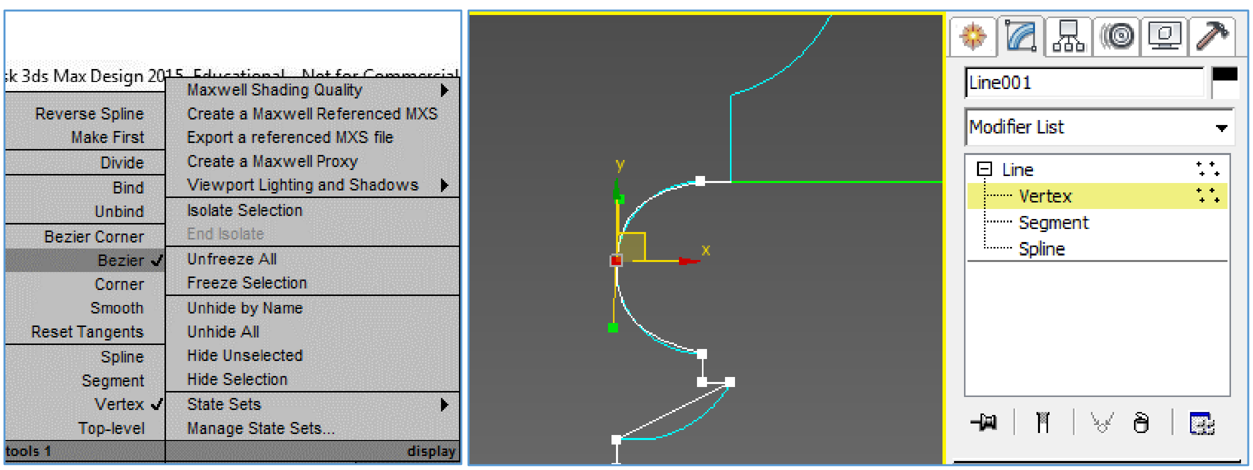


5. Start retracing a profile relying on the reference drawing. Follow the instructor's directions in order to create a simplified contour using the least number of vertices, as shown in the following screenshot:



You should see the snapping tool working by causing a point to jump to an exact position when you drag it to the proximity of the desired vertex. When finished, close the Spline returning to the starting point.

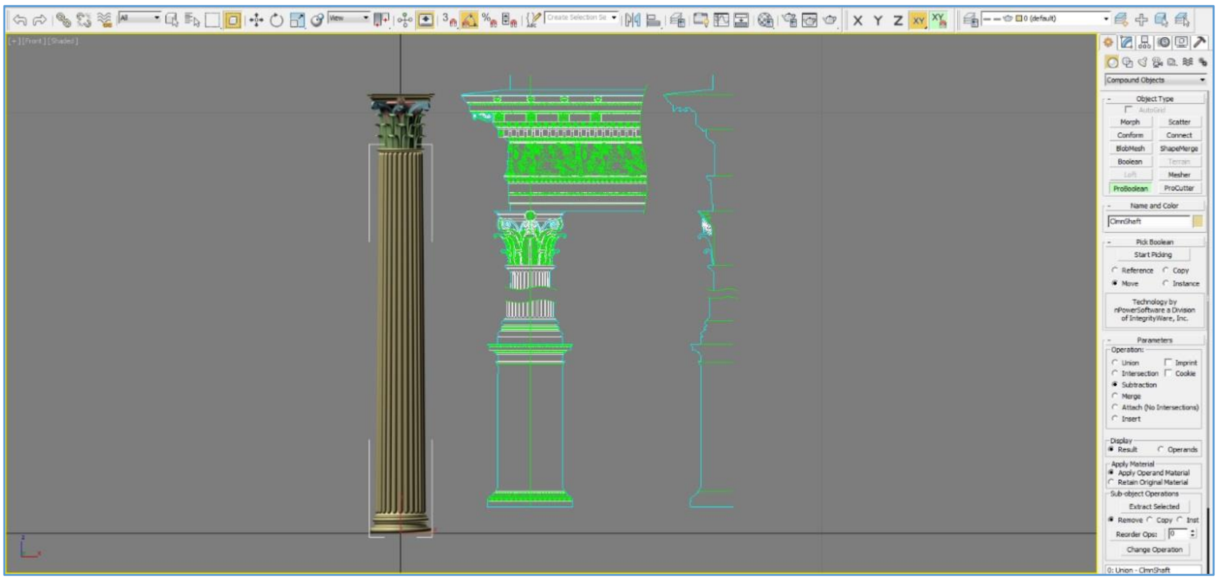
6. In order to turn a broken line into a curved line, you need to convert some corner vertices into **Bezier curves**. Having the new line selected, go to the right **Command Panel** / **Modify Tab**, expand **Line** subcategories by clicking on **+**, and select **Vertex** as shown below:



Select the vertices you want to turn into curves and right-click on one of them. Then check **Bezier** from the tab. You should see now two green grips placed at the ends of the tangent to the vertex. By manipulating them, you can adjust the spline curvature. You can choose **Bezier Corner** option from the list if you need two broken curves instead of one.

Try to change the number of **Steps** in the **Interpolation** tab in order to control the discretization parameter of the curve (see Basics of 3D modeling).

7. Close this file, open the **WIP** / **WS1_tut02** folder, and double-click **WS1_Tut2a.max**.
8. You can find the half profile of the column (ClmnShaft) already prepared. Once selected, browse the **Modifier List** under the right **Command Panel** / **Modify** tab and look for the command **Lathe** (or simply turn it on by clicking on the small light bulb next to the command in order to activate it).
9. Set the number of segments (vertical interpolation) to 24 and make sure that the angle is 360 degrees.
10. Close this file, open the **WIP** / **WS1_tut02** folder, and double click **WS1_Tut2b.max**.
11. Select the object "ClmnShaft" and go to the right **Command Panel** / **Create** tab / **Compound Objects** and select **ProBoolean** command. Make sure that the Boolean operation is **Subtraction** and activate the **Start Picking** button. Then start clicking on the objects (Shape001, 002, 003) that you want to be subtracted from "ClmnShaft". You should see now the grooves being carved out of the column shaft.



12. Deactivate **Start Picking** button. In the Modify Tab, you should see the object modifiers stack collapsed into a Boolean object. Expand its subcategories by clicking on **+**, and select **Operands**.

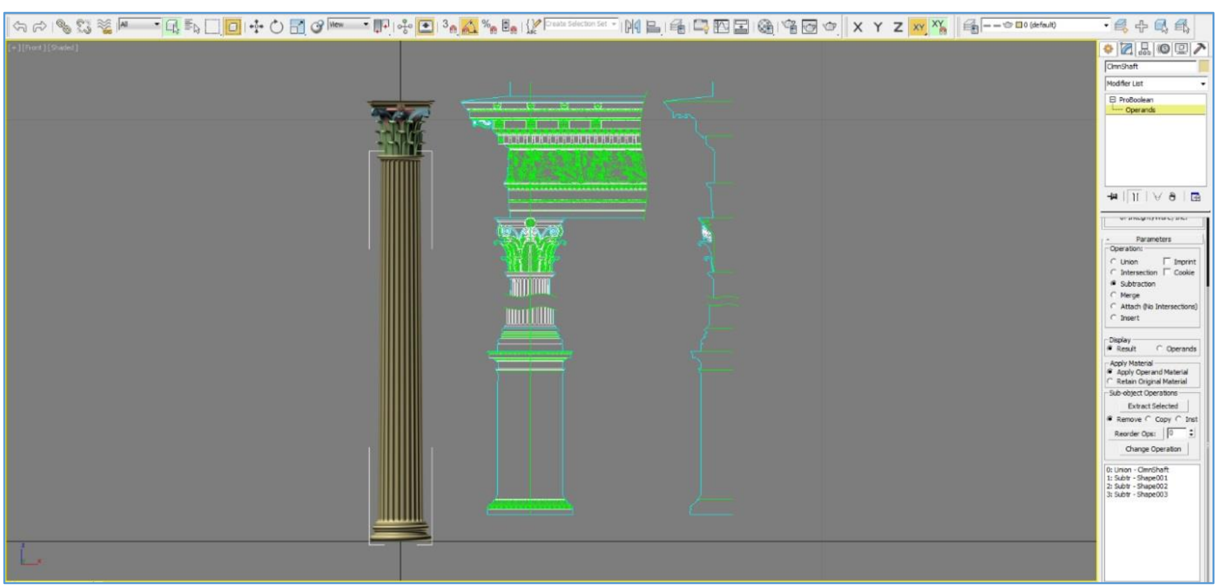
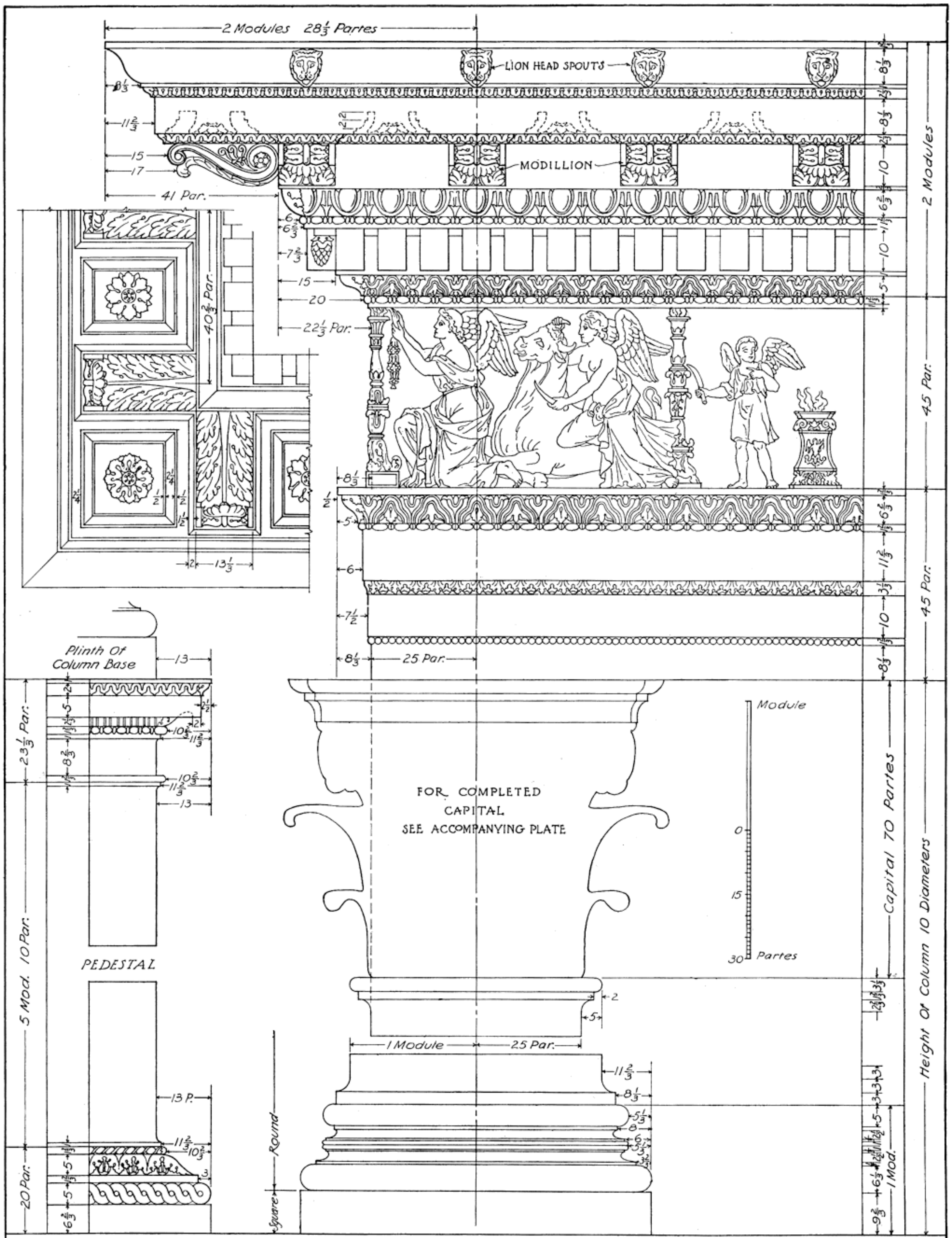


PLATE 70



VIGNOLA'S CORINTHIAN ORDER

Figure 5: Vignola, Pl. 70.

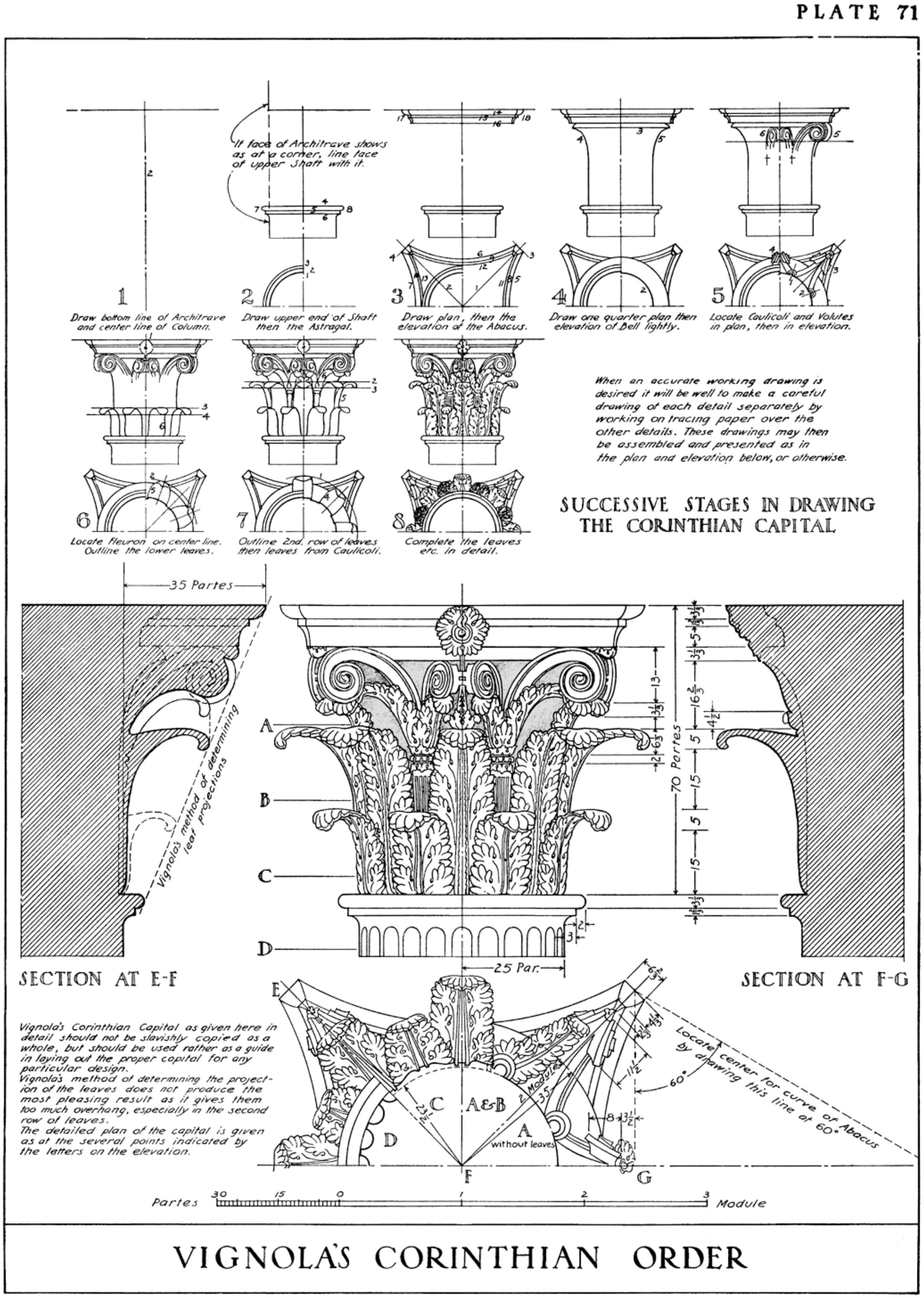


Figure 6: Vignola, Pl. 71.

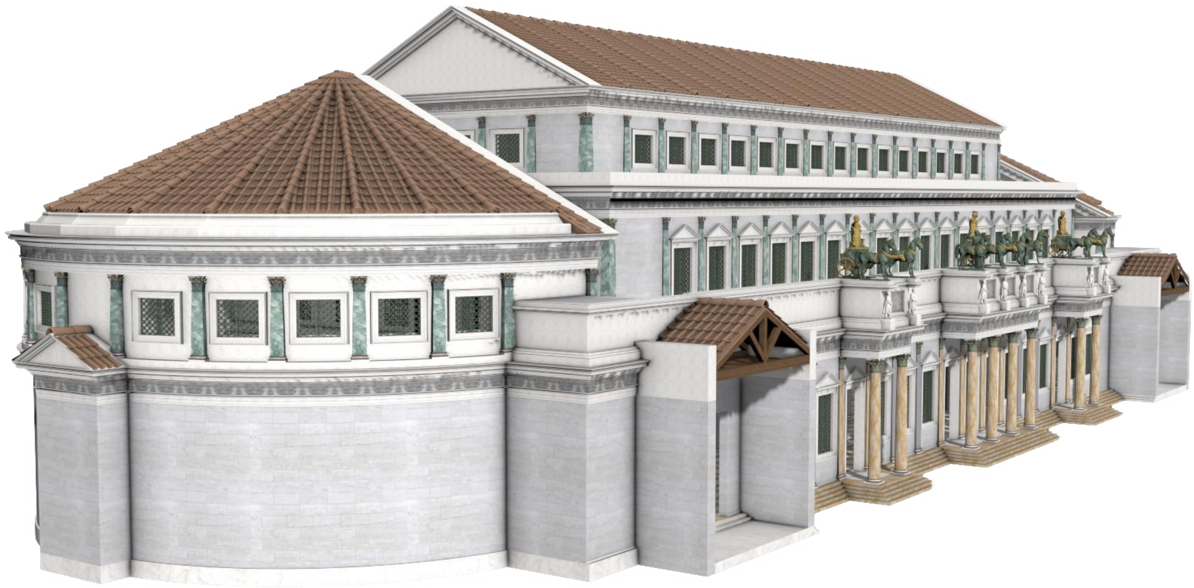


Figure 7: Full rendered model of the Basilica Ulpia façade.

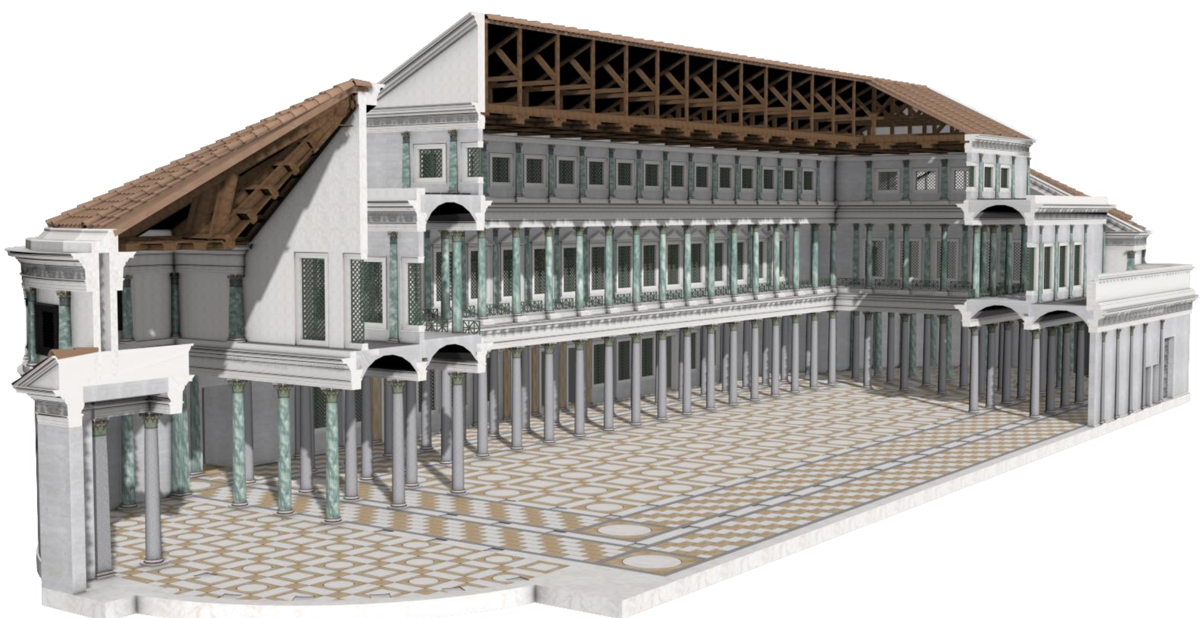


Figure 8: Full rendered cutaway model of the Basilica Ulpia.

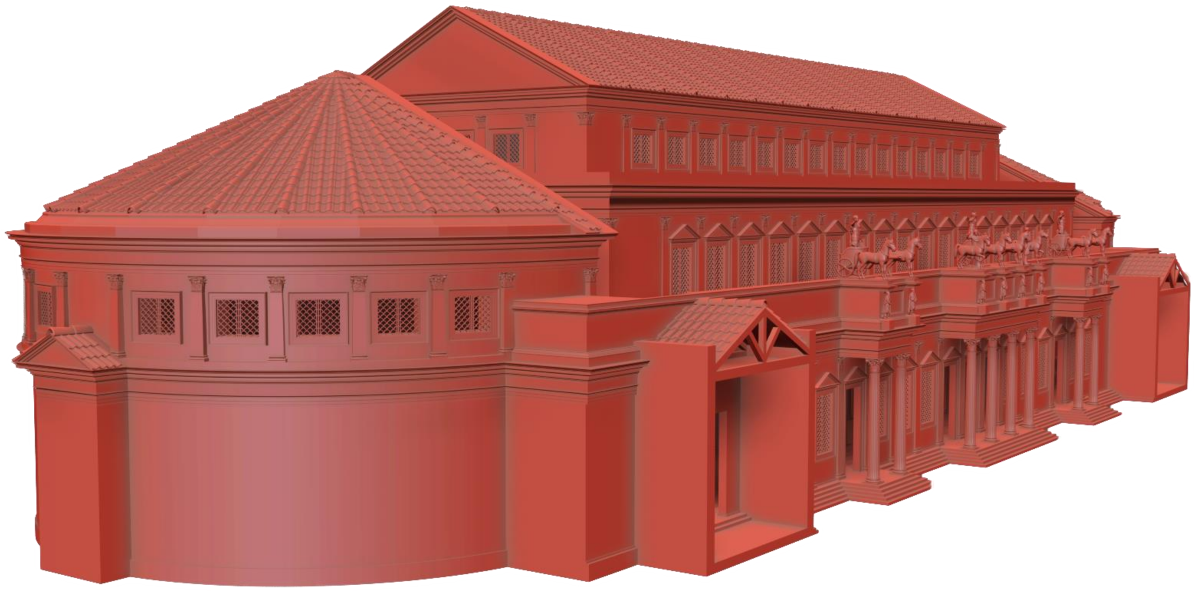


Figure 9: Clay-rendered model of the Basilica Ulpia façade

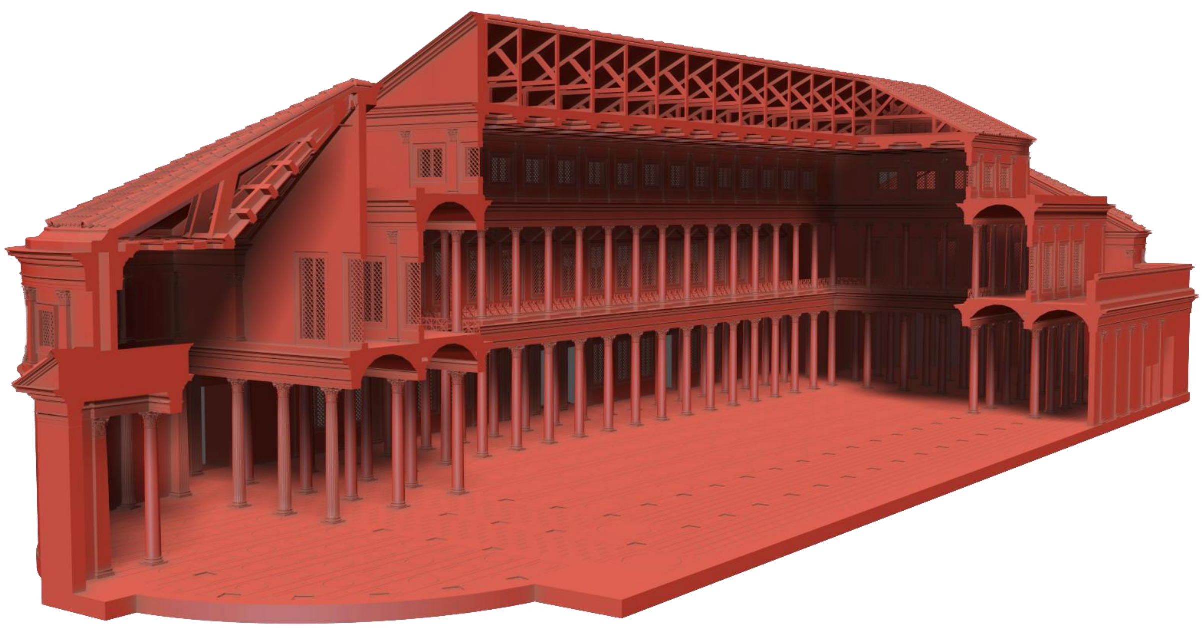


Figure 10: Clay-rendered cutaway model of the Basilica Ulpia.