AS124787

Connecting FormIt and Dynamo for Pre-Design Formal Thinking

David R Beach
Drury University, Hammons School of Architecture

Student Guest Speakers:
Ethan Kaplan, Nia Damgova

Learning Objectives

- Learn how to generate a context model and contextual data for a design project in FormIt
- Learn how to use Dynamo to develop formal design strategies to respond to both analytical data and visceral design thinking
- Learn how to push the model to virtual reality for early design-process exploration and communication
- Learn how to export the model for fabrication, including CNC cutting (site) and 3D printing (design and context)

Description

FormIt software connects 3 elements of the early design process that are relevant to every project: contextual information, building performance simulation, and parametric modification. Learning to connect these pieces quickly and efficiently in the architectural, 3D sketch style environment of FormIt enables quick design iteration opening new modes of design thinking. This session will illustrate a process that we're teaching architecture design students: First, how to quickly build design context (both from data acquisition sites like Flux and the creation of custom models) of buildings and topography. Second, how to develop predesign simulations to inform decisions and create a baseline standard for building performance. And finally, how to develop formal strategies by using parametric processes with Dynamo software connecting design ideas and simulation data. In closing, the session will cover predesign visualization beyond FormIt, pushing the file to fabrication (3D printing and computer numerical control) and virtual reality.

Speaker:

David R. Beach is an architect and Associate Professor of Architecture at the Hammons School of Architecture at Drury University. Specializing in digital design technology, David is an advocate of full digital immersion as part of a traditional design process leveraging technology to inform process, collaboration, and decision making through analysis. David teaches in the architectural design studios, the Center for Community Studies working at the urban design scale, and both the introductory and advanced digital design technology courses. The application elements of David's current research can be found at the blog The Architect's Digital Design Guide, the Autodesk Design

Academy, and his YouTube channel, which combined have over one million views, and are outlets for work and information directly related to questions received from students and practitioners. David has given 5 presentations at AU, and has completed over 24 major conference presentations in the last 9 years.

Generate a context model and contextual data for a design project in FormIt:

Before starting:

Add the Flux to Revit Plug-in:

https://community.flux.io/content/kbentry/2084/revit-plugin-overview.html

Add the FormIt + Revit Plug-in:

https://formit.autodesk.com/page/formit-revit

Download all the course material, and example files here:

https://sites.google.com/view/au17-formit-dynamo/home

Module 1a: Modeling Context – Site (Flux+Revit+FormIt):

Watch the video on Flux to FormIt at (Note: These are expanded screencasts of the overall presentation from AU. There is full "play by play" commentary, no ads, and a consolidated playlist):

Flux to FormIt: https://youtu.be/NJqcrs-ltnk

Wrapping the site in FormIt: https://youtu.be/_qe7ZB4vZok

Steps:

1. Select site and site data in Flux.
2. Import Contours using the Flux toolset in Revit. If you import the geometry as a topography family you can import all of the data you setup in flux, then skip to step
3. Export geometry as .dwg file, and reimport to create a mesh that can be read using the command "Create from Import" under the toposurface tools.
4. Import Roads, Buildings, and other data from Flux that might be relevant in your process.

*Note: we are building a file to run in parallel within multiple states – and this is always crucial to my workflow in a BIM world. I want this data to live in my physical/analogue world via fabrication, my BIM world (Revit), my predesign thinking world (FormIt), my VR world (Live), my cloud (360), and be 100% available for collaboration via any of these avenues. This takes a bit of upfront work sometimes…not much, but some. It is more about attention to what you are getting/building than time. For instance, I want to build most of my context models rather than download them so they work in every instance, and have the level of detail in relation to the data I want to use as a designer. That is more time early on, but less trouble shooting for why something, perhaps, is not fabricating, or rendering correctly in VR, later.

5. Convert the re-imported .dwg topo surface to a Revit topo. Unpin and delete the imported .dwg topo.

6. Under the Model Site toolset, click the arrow (bottom right) in the tool palette, and set topos to every 10 feet.

*Note: This isn't a necessary step, but will reduce the visual information, and improve the clarity of your view in FormIt – just remember that you are looking at topos at 10' later in the process.

7. Copy your 3d view and rename it to "ZZ-FormIt."

*Note: I typically use the "ZZ" prefix on all of my Revit exports so that those 3d views are listed at the end of my 3d view list. I only access them a handful of times throughout a project, so I like them where I don't see them every time I am looking for a specific view. Usually this set of exports will include ZZ-(fabrications), ZZ-(Lives), ZZ-FormIt, and ….

8. In a 3d axonometric view, group each of your imported geometries from Flux.
9. Use the elevation views and site plan views (and I often create a quick disposable section through the middle of my site to help as well) to "roughly" center the building site to the origin location (between the four elevation targets in the default template). This may/will need to be adjusted as your project evolves, but you need to start somewhere, so make a safe assumption about your basic site position.
10. Turn on Section Box in the view properties, and bring the box just inside the edges of the topo surface – this will generate sides to the topo surface (important for both 3d printing and CNC routing), and crop off any lines outside of the topo prior to exporting.

*Note: Centering the site is more of an art than a science to right now this early in the design process. You will have to make assumptions, but you have to start somewhere, and starting with known quantities is better than beginning without context. I know that I want to work in Revit with my entry level floor at 0' on the elevation, so I always move the topography to the building site. I do not move the building to the topography. The Revit world works best (my opinion) when the building is at the center of the Revit world (the X,Y,Z, Cartesian Coordinate System). This will help my files line up across my multiple platforms, so as I move files from Revit to FormIt, FormIt to Revit, Revit to Live, and so on, everything should line up without additional modifications. I loathe reworking data…

11. Export from the 3d view as a .dwg file.
12. Import the .dwg file into FormIt.
13. In FormIt: Before I get too carried away, I want to make the 3d model in FormIt water tight – this will help ensure accurate 3d printing, and may make a difference in the CNC process depending on the software used to create a toolpath (we use PartWorks for our ShopBot, and to be honest, it doesn't care if the object is water tight or not, it just looks for a surface and builds a tool path).
14. Double click the topo surface in FormIt to edit the topo group
15. Double click the outer edge from a view below the topo to edit to geometry that form the four vertical sides under the topography – this will let you select the bottom lines of each piece.
16. Activate the Cover tool, select all four lines that make up the bottom edges, and then click the check box for the cover tool, this will close out the bottom edge of the topography geometry and create a water tight(ish) model.
17. There may be a few additional pieces to delete that get created from this process – notably above the edges of the top of the topo surface, just double click to edit the family, and delete the extra faces.
18. Create a new material and apply it to the topo model – this will allow you to actively adjust the transparency and opacity to see the satellite photo for reference below the topography model.
19. Use the location button in FormIt to establish your location, and import a satellite photo.

20. Move the topography model to line up with the imported satellite photo.

*Note: The satellite photo gives us that extra bit of information that doesn't exist in the Flux drawings – width of roads, foliage and additional site features, and it is an important step to verify that the data is concise and correct.

21. We are ready to start modeling existing buildings and conditions. Woot! The steps become less elaborate from here – it is always crucial to set things up correctly at the beginning of a project!

The completed model is in the course materials section titled: Step 1_Flux-FormIt.axm

Module 2: Modeling Context – Buildings (FormIt+Google Maps+Photoshop):

Watch the video on Context Modeling In FormIt at:

https://youtu.be/zm69Z8flizA

Context modeling is always a bit of a tricky task. There are routines to auto model, sometimes you can find models of existing building (InfraWorks360 is a great resource for that), and you can always use a variety of methods to build point-clouds and objects. All that said, I still prefer teaching a process of modeling the geometry. This reinforces modeling skills to my students, but more importantly, it builds a model that you know. I can be reasonably certain that everything I model will have minimal geometry (to run fast in VR), will be water tight (to do 3d printing), and will be modeled with the data needed in relation to my design process.

1. Create and place topography geometry within appropriate layers for FormIt objects.

*Note: FormIt, like many conceptual modelers, like to autosnap everything. This keeps your tasks moving quickly by making assumptions in a 3d drawing space. However, we need to turn off the topography for a moment to ensure we are modeling existing buildings with a flat base, on the ground plane, then we will move them vertically to the topography.

2. Under the layers tool palette, hide the topography and add an "existing buildings" layer (or multiple layers if that helps you keep things organized).
3. Trace the outer edge of the building – watch for the purple lines to appear as you are tracing out a typical, rectilinear building. The purple line will denote a perpendicular reference to the previous or adjacent line.

*Note: No, this process is not precise to the inch. It is precise within a few feet. Where and when fractions of an inch maters, rely on your professionally created survey. For predesign work, and a basic understanding of context, everything done thus far in the steps is within acceptable tolerances.

4. Reference street view for three key pieces of information: A screen grab of the elevation (using the Print Screen function of most any computer will suffice), the address, and the building height.
5. Estimate the building height in street view by quickly using the surface rectangle in street view. The height of the surface rectangle is approximately 7' on the surface of an elevation, as long as the building is not too tall (perhaps over 8-10 stories) this method will give you a close estimate. Alternatively, you can also use Google Earth to hover over the top of a building and find its height relationship adjacent to the street.
6. Pull the base of the building up by the appropriate height in FormIt.

7. In Photoshop, go to File-New (accept the defaults) and Edit-Paste paste your screen grab (from the Print Screen function). Take the elevation out of perspective by using guides and the transform toolset. Crop and save the file as a *.jpg.

*Note: I typically name recommend a naming convention on existing buildings that utilizes the address of the building. The texture map in this example is: 1830 Main East.jpg. Using this method, combined with naming the geometry by the address as well, will keep things reasonably organized and capable of being dissected by other team members working with the file.

8. In FormIt, create a new material and assign the elevation *.jpg as the map.
9. Measure the height and width of your geometry in FormIt and apply those values as the height and width for the texture map.
10. Assign the new material to the elevation surface.
11. Details:

*Note: Detail is relative. Working in 3d modeling you can zoom in and model the inner workings of a lockset if you desire to, but the detail should relate directly to what you need. The closer I work to the project site; the more detail I might add. Typically for context, that may include simple recessions in the surfaces for windows and doors, projections for major elements coming off of the façade, and basic formations around the roof edge and/or parapet. Moving further away from the project site, I typically stick with basic building massing.

12. Use the line tool to draw out guides across the surface of the elevation, being careful to never create new geometry, and being careful to ensure that your line work is on the surface of the elevation.

*Note: Creating new geometry will remap the material to the new surface, making a bit of a mess of the elevation. Hold off on creating new geometry until you do not need the material for reference. To draw the guide lines correctly, the best practice is to start at on edge looking for the “on edge” snap. Draw your line across the surface and look for the “on face” or “perpendicular” snap on the second click of your line. Rogue lines (lines that are not coplanar with the elevation surface) will not behave in a predictable way as you modify the elevation surface.

13. Once the guides are drawn in, finalize the creation of new surface geometry and push in, or pull out the appropriate elements to convey pattern, scale, entry, and additional elements that help explain the design context.
14. Continue to use street view to add additional geometry, and when finished apply a new material to the building to remove the texture maps.
15. Before moving on to the next building, there are two important steps:
    a. First, double click any surface and turn the building into a group. Name the group with the street address for the building.
    b. Turn the topography surface back on the in the layers panel and move the building vertically to the topography surface. Often you will need to pull the bottom of the building down to ensure that corners are not “floating” above the topography. At times you may also want to move the building vertically to the topography prior to adding detail if there are extreme slopes involved that may help determine the placement of exterior elements like doors and windows.
16. The process is repeated for the remaining buildings. A rule of thumb for me – I am willing to spend up to an hour on buildings adjacent to the site, no more than 15 minutes on buildings within the block, and no more than 5 minutes beyond that. For me, it is a simple issue of time and money. Provided the appropriate time and funding, model away – FormIt is very capable of adding an intense amount of geometry to replicate existing

conditions which may help in visuals, but may not be as relevant in your specific design process.

Module 3: Predesign Simulation (FormIt):

Watch the video on Predesign Simulation at:

https://youtu.be/bcaSLtMIUQM

It is never too early to start creating building data. At this point in the process you have a site, constraints, physical context, and something close to a building program. Given that data, we can begin to build some baseline studies on how a building will perform within the context. While very little has been done to validate the necessity of predesign simulation, climate expert Joseph Romm has observed through his research that “when just 1 percent of a project’s upfront costs are spent…up to 70 percent of its life cycle costs may already be determined.”

1. Turn off the topography layer. We will need to draw on the surface to make sure we are drawing a level base.
2. Sketch out the base (keep it simple, rectangles are good) of your building footprint paying special attention to square footage based off of your building program.
3. Double click the form, and create a group.
4. Under the object’s properties (instance properties), give it a name and check the “use levels” box.
5. Under the Levels panel, set level heights, and names. Verify both the floor level and total square footage numbers in comparison to your program document for the building design.

*Note: Setting levels for an object in FormIt denotes the object as a design element to run simulations on. When there are context models within the workspace, having levels selected helps the software understand where to look for surfaces and interior spaces to form the building simulation.

6. Starting with an initial pass on Solar Analysis, double click any surface on your building instance and run the solar analysis.
7. For a location in the Midwest, observing the Month Peak setting for the initial reading is probably the most beneficial.

*Note: Temperate climates like Kansas City have temperatures that swing drastically from summer to winter, resulting in the need to block the sun through the extreme temperatures in the summer (July and August), while leveraging solar radiation in the coldest months (January and February).

8. Export several of the views as images for reference. We will revisit these surfaces and numbers later on in the process. These numbers will also be useful for building calculations on solar panel potentials (which is outside the scope of this class).

*Note: A BTU, or British Thermal Unit is the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit. An imprecise but simple, and relevant example that I use with my students to quantify this number is the rule of a light giving off 3.4 BTU’s per watt. So, a 100 watt incandescent light bulb (not sure you can even find them anymore, but everyone can understand they are a “burn your fingers” kind of hot) gives off 340 BTU’s. Looking at the example project in August, when temperatures in Kansas City are often at their most extreme, the South façade has a reading of 151 BTU/sq ft. You could imagine this as a total of 543,600 BTU's across the surface (120' long x 30' tall = 3600 sq ft. 3,600 x 151 = 543,600 BTU's) amounting to 1,599 100 watt incandescent light bulbs even spaced across the surface of a wall in August. The interior of the wall is trying to maintain a comfortable 75 degrees Fahrenheit while the exterior ambient temperature is in the mid 90's, with 1600 100 watt lightbulbs spread across the surface. This is a wall really battling the conditions, and a wall requiring design attention as it is also primary street front property with excellent views in and out. Compromise is a good word, and part of what a designer must consider in similar conditions.

9. Turn off the solar analysis tool, and be sure to open the file in the online version of FormIt.
10. Save your FormIt file to your A360 drive, and open the project in the web browser version of FormIt.
11. Select the location button and click on the adjacent weather station on the location map. This will provide you with both an annual wind rose, as well as monthly (seasonal) wind roses where we can look at the direction and severity of wind. In a location like Kansas City, the winter winds are of a completely different quality than the summer wind. Do a screen capture of the key wind roses and save them to your project directory.
12. To start the energy analysis, hide all of the layers outside of your proposed design.
13. Click the Generate Insight button, and continue working on other things (perhaps an espresso) while waiting what is typically only a few minutes for the results.
14. Once completed, click View Insight to study the results and to begin working through values that might shape your design thinking.
15. Pay special attention to the following tiles:
    a. Windows
    b. Roof and wall constructions

*Note: Leveraging information from the simulation and data acquisition steps should help inform both you, and your client's decisions regarding several schematic decisions. On sites that are more open, several passes at the initial data should be done with the building in different configurations including rotation and varying length, width and height proportions.

Dynamo for developing formal design strategies to respond to both analytical data and visceral design thinking:

Module 4: Building Programmatic Design Thinking in Context (Dynamo+FormIt):

Watch the video on Programmatic Design in Context at:

https://youtu.be/mQE-X6ej4gw

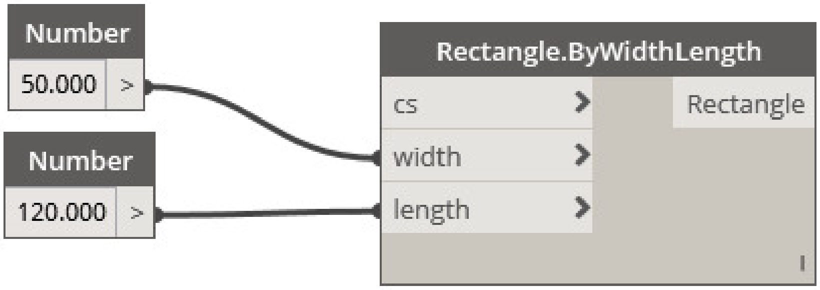
1. *Dynamo!* Launch Dynamo.

*Note 1: There are several versions (flavors) of Dynamo, including versions specifically for Revit, Web, and the standalone version Dynamo Studio. To leverage Dynamo within the FormIt environment your only current choice is Dynamo Studio. The studio version contains the process that allows us to upload a script to the cloud, and then utilize that script from the cloud in the FormIt workspace.

*Note 2: It should come as no surprise that diving into a visual programming environment is intimidating. I am someone that is on a similar learning curve, acknowledging that this mode of design, process, and computation is an extremely relevant part of moving forward with technology. One of the keys to learning Dynamo is developing a strong understanding of what the potential uses are by applying examples from relevant scripts, and how to repurpose what is already available. The following segments hope to both show how to create custom scripts, and work with packages published by others and available for use. For most users, you will be making minor modifications to relevant scripts that already exist. Having a basic understanding of how the scripts are functioning will make it relatively easy to pick apart an existing script and reapply it for your specific task. One key hurdle to get over on the quest to learn Dynamo is learning the nodes (a node is one of the predefined boxes in the Dynamo workspace with input and output ports). As you develop what you would like a script to do, finding the appropriate nodes takes practice, and the patience to build a new language of nodes with cause and effect. Finally, while this is speculation on my part, there is plenty of evidence available to suggest that visual scripting programs like Dynamo will be the bridge connecting designers to the effective use of artificial intelligence in design. Scripts will be able to set up the routines that select, parse, and actively run routines versus a set of predefined variables to generate, or guide, a designer through options leveraging AI. This is again a bit of speculation on my part, but there is also, again, plenty of evidence to suggest that AI will be the technological disruption…not just a disruption.

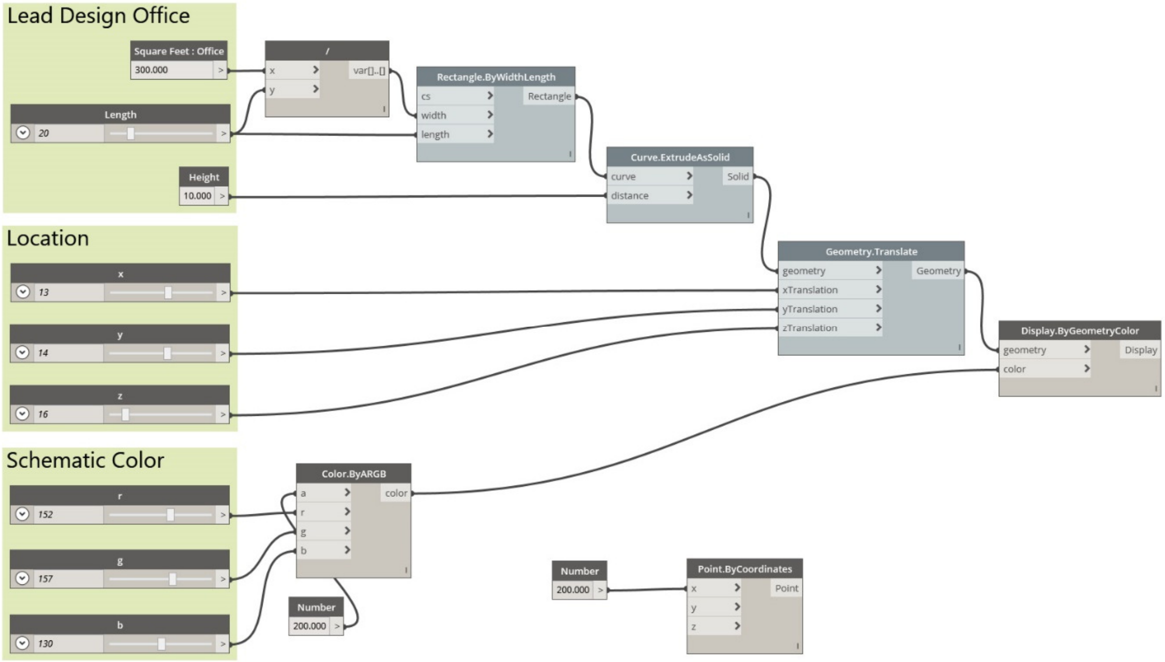
*Note 3: Especially for the designer that is learning to develop spatial programming, building a better diagram of spaces and their relationships is key in making successful designs. For me, the necessity of teaching this mode of thinking (building programming), with the immerging necessity of learning visual programming (Dynamo), creates a perfect opportunity. The following script was developed to introduce the two topics together with a programming/programming assignment:

2. Create the site base (site context to work within) by building the following script:



*Note: This script creates the basic rectangular space that all of the programmatic elements need to fit within. Dynamo Studio does not have specific units, but importing a script from Dynamo Studio to FormIt will convert your units to feet. So, 50x120 can safely be assumed as 50’ x 120’. You also need to make an assumption regarding polar coordinates. I typically assume that positive X is north, and positive Y is west. A more complex site can be made from a series of points using the “Point.ByCoordinates” node and providing X and Y numerical inputs for each point.

3. Build the following script. Groups were created for space name and data, its location, and its color. The groups don’t really follow any function other than providing visual clarity, and important part of visual programming.



4. Select all of the nodes, copy and paste, and overwrite the properties for the grouping title, and the square feet.

Note: This script is pretty simple. Take a number representing a required amount of square feet. Plug that number into a division node, and divide by an amount generated by a numerical slider. This creates a variable that is one half of the definition of a rectangle. The other half of the numerical definition is the slider (length) that was also the denominator in the division node. This creates an equation where no matter the length number in the slider, you always have the same square footage represented in the rectangle. The remaining nodes exist to help represent the required square footage as a three dimensional form with a specific color.

5. Use the location sliders to move the programmatic spaces along the X,Y,Z coordinate system. Add additional spaces as required, paying special attention to connective pieces like vertical circulation, appropriate adjacencies, and consider the type of space according to its location within the context and building design. The next step will be to push the Dynamo package to the cloud, and import the package into FormIt for testing within the context.
6. The last step within Dynamo is to save select File-Save to Web. This will send the file to your 360 account, and make the script available within FormIt.
7. In FormIt, open up the Dynamo window and update available scripts by selecting the Refresh button. Select your script and place it by clicking in the FormIt work space.
8. To edit the available values in FormIt, double click the geometry created by the script, and make sure that the properties window opens. All of the available values from the script will be available to edit in FormIt.

*Note: Make major modifications within Dynamo! The process is a bit slower in FormIt, and the variables are not as easy to navigate if you have a large number of options to manage.

Module 5: Developing Structural Concepts Using Existing Dynamo Scripts (Dynamo+FormIt):

Watch the video on Dynamo and FormIt here:

https://youtu.be/1X-WNda3H7E

1. Load the Column Grid script by Josh Goldstein onto your 360 storage by opening the script in Dynamo Studio, and using the “save to web” function.

*Note: you can simply load a script from any shared location online. However, if you didn’t write that script, you may not be in control of it. Any changes made in the script will be transmitted to your FormIt file the next time you insert the Dynamo script into your workspace.

2. Adjust the attributes to begin working with the building form.
3. Continue adding column grid geometry to your FormIt workspace. Each one is an independent instance with its own variables.

*Note: you can work while the script generates modifications to the geometry. For working with something like a column grid script, I will collect a measurement that the structure needs to adapt to, modify a variable within the script, and while the geometry is updating I will gather the next measurement needed. Creating a flexible, adaptable structural system into a predesign process builds an absolute sense of joy for me. It is excellent to quickly iterate possible options to build an understanding of how structure can be implicitly related to, and yet independently expressed with enclosure and space.

Module 6: Developing and Testing Enclosure Systems (Dynamo+Fractal+FormIt):

Watch the video on Dynamo and FormIt here:

https://youtu.be/g1j9Rv7L32E

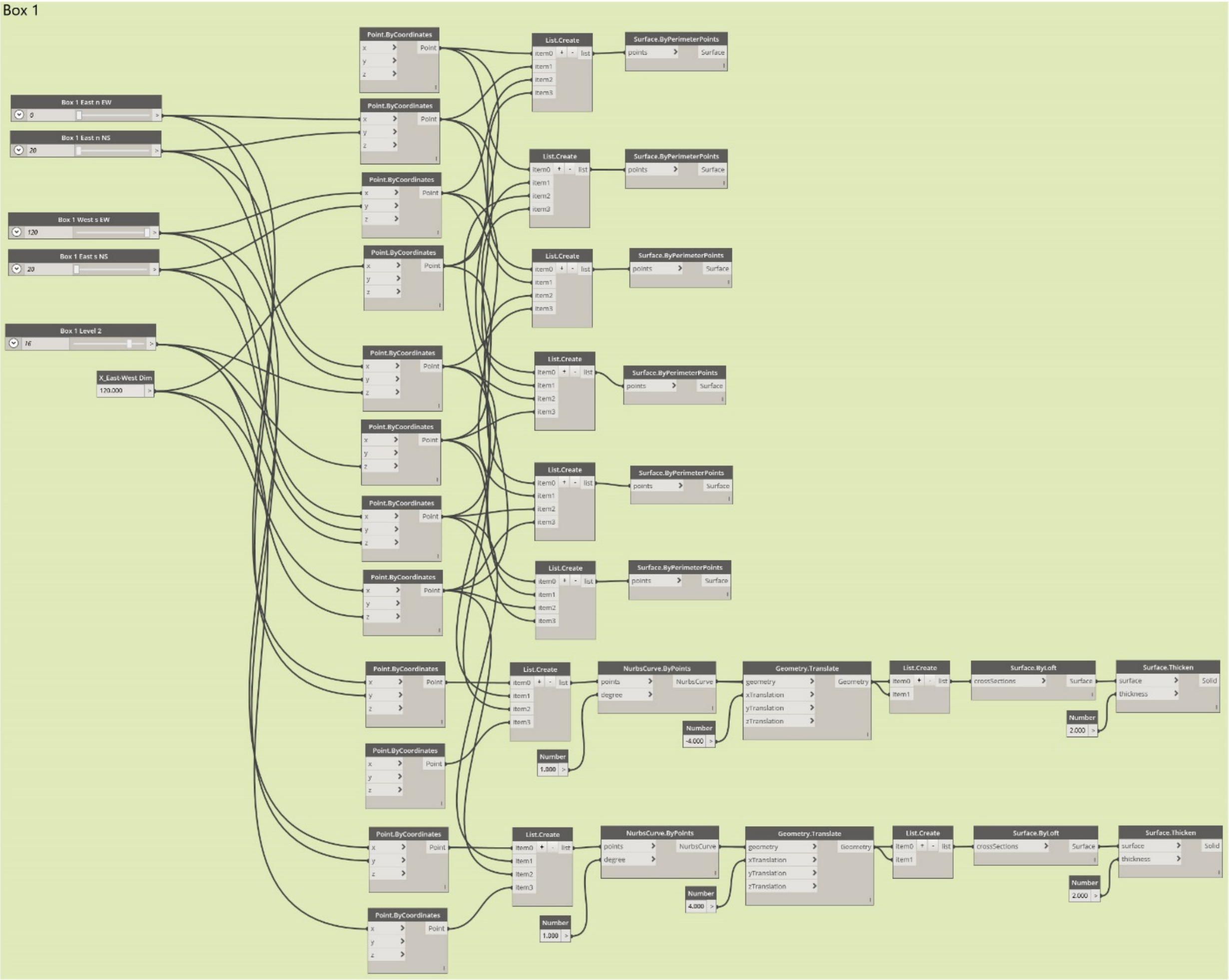
This process is identical to Module 5, but using a script to add louvers to a test façade. The module also continues on to reuse the steps within the solar analysis tool set to look at the impact of the louvers.

Module 7: Developing and Testing Building Forms (Dynamo+Fractal+FormIt):

Watch the video on Enclosure Experiments:

https://youtu.be/fNZBsscJg0c
*Note: Building design often happens from two different ends of a spectrum – form follows function, and form elevates function. Teaching has taught me to be more of a valuest, specifically that I am happy when I can track a logical process of design thinking. So to approach this process from a different angle with a similar toolset, we can begin to study the enclosure system through a set of variables to create forms for evaluation. A key that should be noted with visual programming and Dynamo, the additional upfront work builds the opportunity for additional variables and iteration on the back end.

1. Build the following script in Dynamo Studio:



*Note: If the text is not legible in your print or *.pdf version of the script image, just grab the *.dyn file from the project data associated with the presentation.

2. Select the nodes, and copy paste to add additional enclosure elements. Vary the height and width and length inputs. Verify that the sliders do not push the geometry out of the building site. Try to avoid conflicts that will cause the geometry to “fold in” on itself which will throw out a warning, and void your form.
3. Save the file to the web, and open up project fractal at:

https://www.fractal.live

4. Inside of Project Fractal, develop iterations of the basic form using the “random 10” options.
5. Peruse the options, download the models that warrant further exploration, and import them into FormIt for evaluation using File – Import 3d model tool.

Module 8: Leveraging Virtual Reality for Design Thinking:

Watch the video on FormIt to VR here:

https://youtu.be/_bbx8ntptkk

1. Use the FormIt import plug-in inside of the Revit Add-ins menu to import the different elements from various FormIt scenes for evaluation in VR through Revit Live.
2. Make basic modifications in FormIt if you are not planning on making additional modifications, or adding additional detail in Revit such as:
    a. Delete any faces that may represent glass. It is easier to just remove them then to try and get the glass to work/look perfect. Having a simple opening will suffice for design review, and it is much quicker to just hit the delete button.
    b. Make any quick material modifications just for visual identity. Photorealism in VR is not an issue at this stage, understanding scale, form, proportion, line of site, and other design issues that VR is excellent at are your key issues for evaluation.
3. Click the Go Live button under the View menu and grab a coffee. In about 15 minutes you will have a VR ready scene. Remember, pack multiple elements into a single Revit scene. Navigation is quick and simple in VR, and having multiple options in a single Revit scene can allow for a side by side evaluation of design ideas.

*Note: As designers, we have been using the term scale as it applies to representation techniques wrong for decades. I did not realize this until we began working with Dev Kit 1 on the Oculus Rift. A perspective drawing or rendering provides proportion, VR provides an actual sense of scale displaying specifically how your body will relate to a design.

Module 9: FormIt to Fabrication with 3d Printing:

Watch the video on FormIt to Fabrication here:

https://youtu.be/FfasJglPLjM

1. Wow! You are still with me reading the handout. Excellent!!
2. In FormIt, select the objects that you want to export as a *.stl file for slicing and sending to a 3d printer.
3. In the export dialogue box, chose either “selected only” or “all objects” or “visible” based on what specifically you want to print.
4. Import the *.stl file into your printer/slicer software and verify your scale. You can use the Excel spread sheet in the materials hand out, but you need to verify a few files for accuracy (the spreadsheet is based on the concept that most architectural software works in feet, most slicer software works in millimeters as a method of scale conversion factors).
5. Watch for overhangs within the printing process!!