Small Scale Plant Model, Fall 2014

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Abstract

During the fall semester of 2014, the Small Scale Plant Model Team worked on repairing the current small scale plant model and began using AutoCAD to 3D print a small scale model of AguaClara plants. The purpose of using AutoCAD to print models of AguaClara plants, rather than using Rhinoceros 5, is to automate as much of the printing process as possible. The team evaluated multiple methods of converting a solid in AutoCAD to a meshed solid. In addition, the team looked into alternative printers that would be more compatible to printing using AutoCAD. Eventually, the team hopes to develop a system where anyone can request an STL file containing the design of the most up to date design of an AguaClara plant at any flow rate. Upon request, this STL file should be sent to any 3D print shop to be printed.

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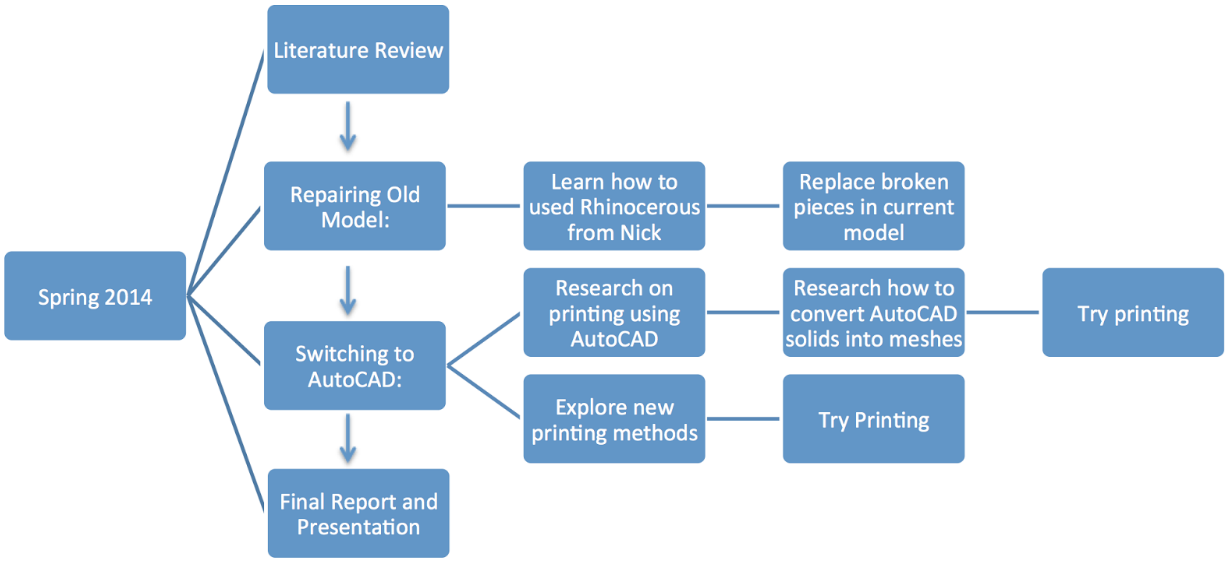
Task List

Task Map



Task Details

1. *Literature Review/October 5th*
    a. Read and understand the team's final report from Fall 2013
2. *Repairing Old Model/December 9th*
    a. Nick Cassab Gheta will teach the team how to use Rhinoceros
    b. The current small scale plant model will be examined and the team will determine which parts need to be replaced
    c. The pieces that need to be replaced should be printed at the Rhodes Hall Rapid Prototyping Lab
3. Switching to AutoCAD/December 8th
    a. Do research on of 3D printing with AutoCAD
    b. Learn how to convert a sold into a mesh in AutoCAD
    c. Determine which functions and commands to use when converting solids to meshes. Figure out if new plugins are needed
4. Explore Other Printing Methods/December 6th
    a. Look into alternative printing methods
    b. Print a sample tank and pipe to see if the new method is compatible with AutoCAD
5. *Final Report Presentation/By the End of the Semester*
    a. Create and submit a final report that logs and explains all of the progress made this semester.

Introduction

Understanding the layout and processes of AguaClara plants can be difficult if one has never seen an AguaClara plant. This team will design and create a small scale plant that can be used to demonstrate how the plant is laid out, where each process takes place, and how it can be taken apart for cleaning. Students, donors, and partners will benefit from the small scale plant as they will be able to more easily understand how it works.

The current small scale plant model is too large to transport easily and has suffered significant damage from air travel. The next version of the small scale plant must use the latest version of the design from the design tool and be built at a scale that makes it easy to transport in carry on luggage. It must also be designed to have all of the components held securely so that shifting between components doesn't cause breakage. Design for transport is critical and thus the design must include a base as well as a protective box.

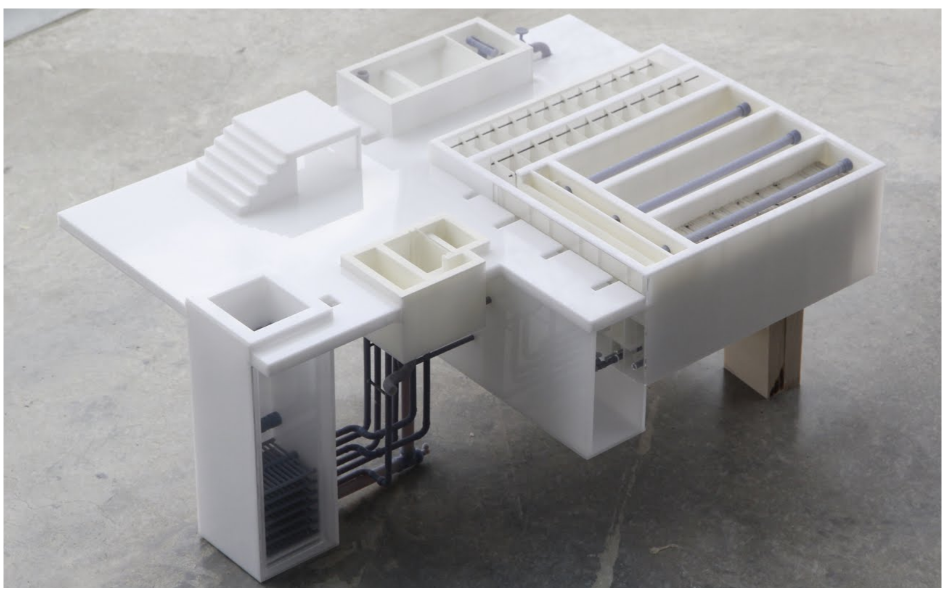


Figure I: Photograph of the current small scale plant model

The challenge details include designing and constructing a small scale plant that can be used to present the AguaClara design. This model should look like a model created from the design tool and each component of the plant should be labeled. In addition, the model should be able to be taken apart like a full scale plant.

Literature Review

- http://aguaclara.cornell.edu/projects/

This page of the AguaClara website lists the eight completed plants in Honduras, their design flow in L/s, and other important statistics. So far, the average flow capacity is 13.75 L/s, which, when compared with existing plant designs, is closest to the capacity of 12 L/s. As a result, we've decided the 12 L/s plant best represents the existing AguaClara plants, and will use the 12 L/s plans in the designing of our scale model. It is the team's hope that the use of this flow rate will allow our project to be as broadly applicable as possible.

- http://designserver.cee.cornell.edu/Designs/etflocsedfi/5363/12Lps/Index.html

This page features PDFs, AutoCAD drawing files, and Word documents that depict a 12 L/s plant, including many dimensional and technical specifications. Various diagrams and figures illustrating plant processes have aided our team's spatial understanding of the plant. The Spring 2013 team used the drawing (.dwg) file featured on this design page to create laser-cutting templates for all flat planes in the water treatment plant. These pieces were scaled with AutoCAD and Rhinoceros, an architectural modeling software.

- Component Templates: https://confluence.cornell.edu/display/AGUACLARA/Small+Scale+Plant+Model+References

All Small Scale Plant Model component templates created by the Spring 2013 team can be found in PDF form on the team's wiki page; these files were created in Rhinoceros by the team from existing AutoCAD design files. The templates are to-scale, facilitating the construction of our plant model and mock-up, with the scaling factor used indicated in in-page comments on the wiki. The team has processed and uploaded top views of the plant in both 1:20 and 1:30, which lend perspective to the size of the plant model. These PDFs can be found under the “References” heading. Preliminary component templates of the totality of the plant models parts can also be found under the heading “Component Templates (1:20).” These include the entrance tank, flocculator, sedimentation tank, filter, staircase, main floor or “base” of the plant, and files separated and targeted for transparency. Again, each of these templates is scaled by a factor of 1:20. As PDFs, these files have the benefit of being easier to view than drawing files. They are also easily printed, a feature of which we have taken advantage.

- https://confluence.cornell.edu/download/attachments/207948359/SSPMFinalReportSpring2013.pdf?version=1&modificationDate=1368162794000

This final report prepared by the Spring 2013 Small Scale Model Team details the progress that they made in the spring 2013 semester towards completing a finished model. They determined the 1:20 scaling factor for the model by consolidating its need to depict specific technologies in the AguaClara process with its need to be compact and readily transportable. The team also laid the groundwork for the construction of the model by developing templates in AutoCad so that it can be assembled with plexiglass pieces. They also constructed a mock-up model of the plant from cardboard which included the main base of the plant, the flocculator, filter, and filter inlet.The Summer 2013 team intends to finalize the work started by the Spring 2013 team and complete the model by first editing all of the templates to account for the finite thickness of plexiglass and then formatting them to be used for water cutting instead of laser cutting. The team will also prepare a manual to allow for future small scale models to be built in a timely manner using the existing templates that we will have developed.

Previous Work

Spring 2013

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Fall 2013

- https://confluence.cornell.edu/download/attachments/207948359/Aguaclara_FinalReport_Fall2013.pdf?version=1&modificationDate=1387119166000&api=v2

This final report prepared by the Fall 2013 Small Scale Model Team details the progress that they made last semester to complete a model. They created a small scale pant model at a

1:20 scaling factor. This model was made of 3D printed parts and plexiglass containers. The blue pieces of the model were hydraulic components printed at the Fabrication Shop in Rand Hall. The white parts were printed from Shapeways due to their size. Finally, the plexiglass was manually laser cut at the Fabrication Shop in Rand Hall. Parts of the model were fabricated differently to be more economical, as 3D printing large pieces can be quite expensive. AguaClara retains the original 3D print Rhinoceros files which can be formatted and are ready for additional 3D printing, should the need arise.

Methods

Repairing Old Model

The current small scale plant model has been damaged due to air travel. Thus, it is important to replace the broken pieces. Most of the hydraulic components connecting the Inlet and Outlet tanks for the Stacked Rapid Sand Filter to the Stacked Rapid Sand Filter have completely broken off.

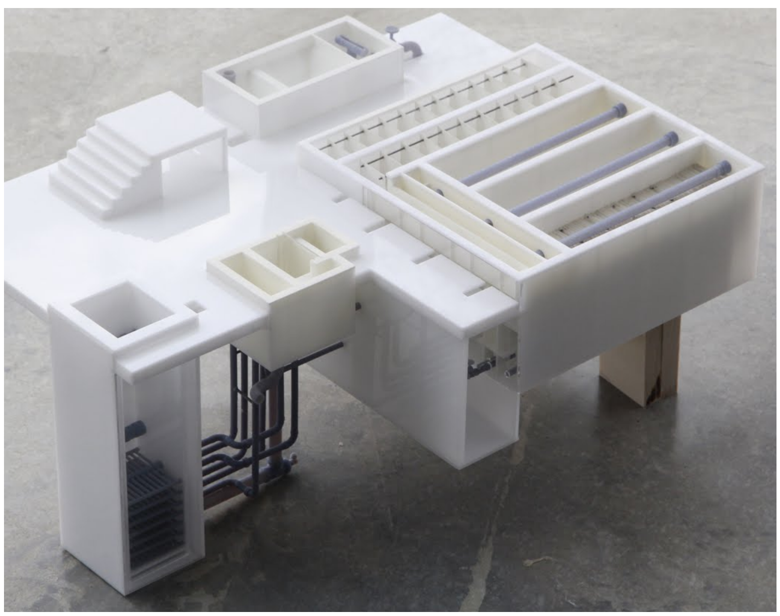

Figure II: Photograph of the current small scale plant model when it was originally built

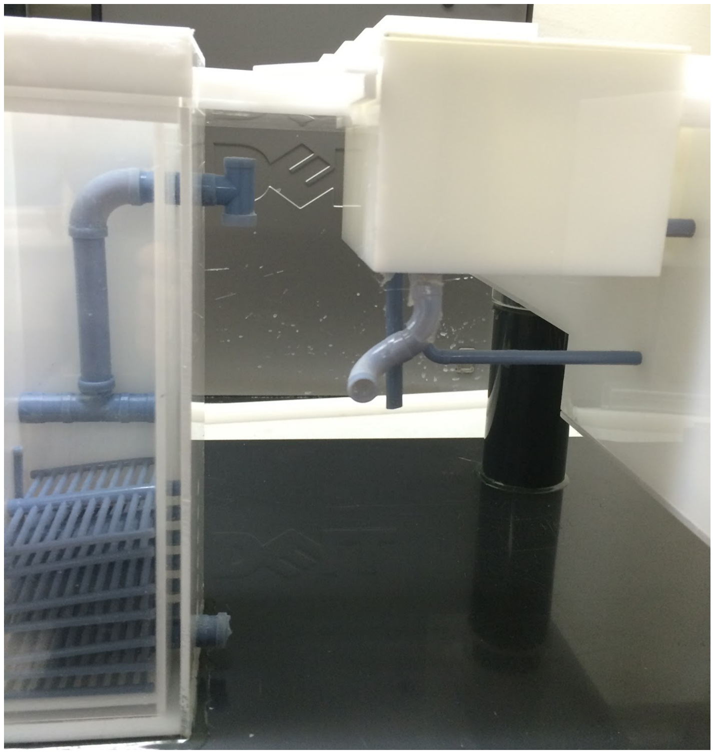

Figure III: Current state of the current small scale plant model

Replacing these pieces required the manipulation of the original printing file created by the Small Scale Plant Model Team in the spring of 2013. This manipulation involved locating the parts that needed to be replaced in the original Rhinoceros 5 file and putting them in their own layer in a new file. The objects in this layer were then reorganized to optimize space. Daniel Salomon from the Rand Hall Fabrication Lab assisted the team with this process. This layer should be printed using an Objet30 3D printer from the Rhodes Hall Rapid Prototyping Lab. This can be done overnight. Originally, the team planned on printing these pieces out at the Fabrication Shop in Rand Hall which would have cost over one hundred dollars, but the Rapid Prototyping Lab in Rhodes hall printed out the parts free of charge.

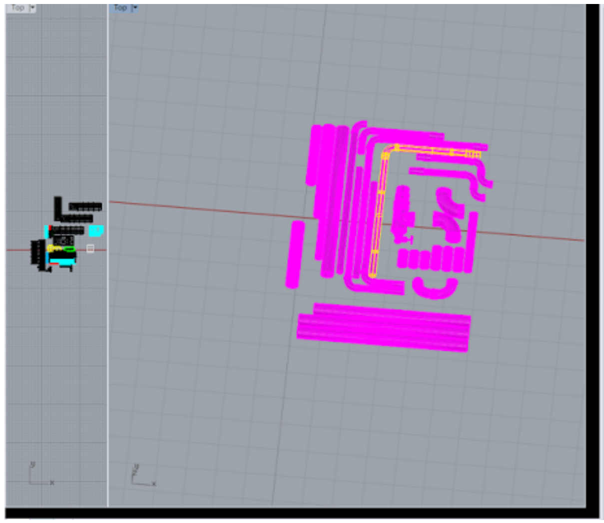

Figure IV: Rhinoceros 5 layer for the replacement pipes

Switching to AutoCAD

The current Small Scale Plant Model was designed in AutoCAD and Rhinoceros 5 used to alter this design to make it printable. AutoCAD created the original design using the design MathCAD files, then the objects in this file were exported and manipulated in Rhinoceros 5 by students from the Cornell University College of Architecture, Art, and Planning. This process can be tedious. Also, AguaClara is already very familiar with AutoCAD and MathCAD so it would be easier more productive if team were to avoid using Rhinoceros 5. If the printing process used AutoCAD and MathCAD only, there is potential for the entire process to be automated. Ideally, the Small Scale Plant Model Team would like to automate the entire printing process from designing to printing.

Using AutoCAD rather than Rhinoceros 5 required the reevaluation of the entire printing process. In order to automate the printing process, it would be extremely difficult to have to separate parts of the plant for printing. The Small Scale Plant Model Team in the fall of 2013 manually separated parts of the plant in Rhinoceros 5 because printing in the z-direction, up and down, was expensive. Thus, hydraulic components of the plant were separated from the rest of the design and printed in its own flat layer. It will be difficult to create a code in MathCAD that could reorganize parts of the plant based on their height. So, it makes more sense to look for an alternative that is still economical but does not require parts of the design to be disassembled.

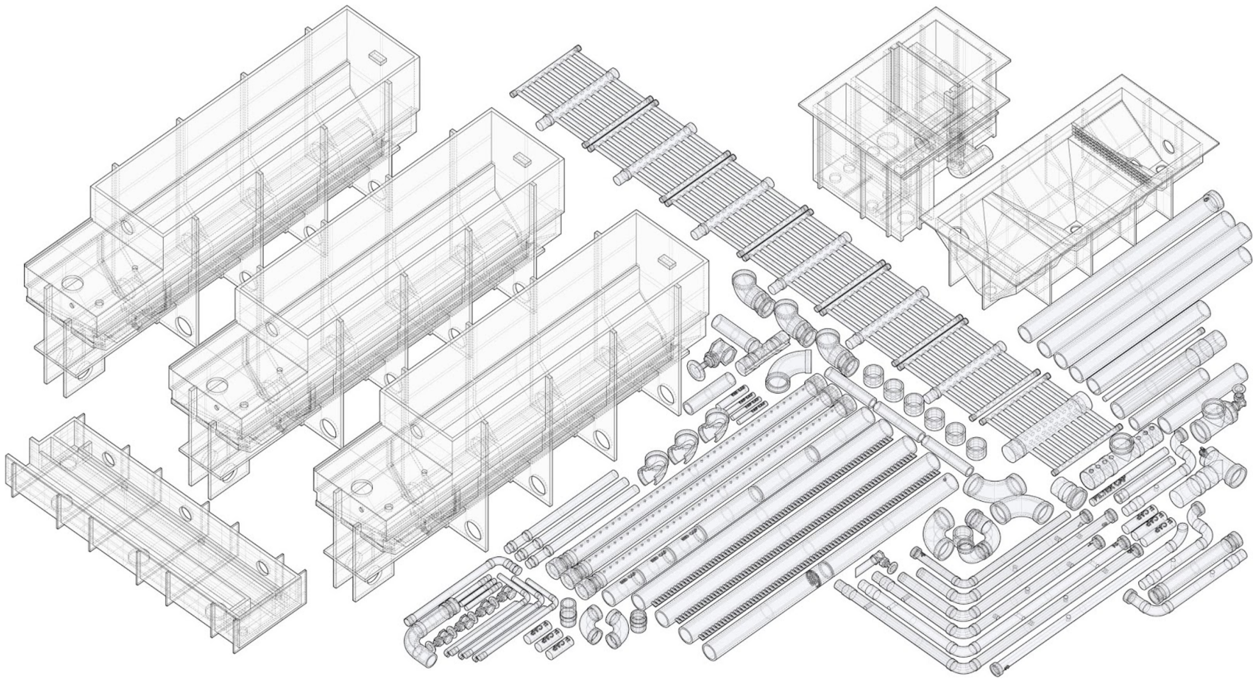

Figure V: Rhinoceros image of the plant components separated

The uPrint SE is a 3D printer available at the Rapid Prototyping Lab at Rhodes Hall. This printer, unlike the Objet30 printer, prints support material that can be dissolved using a base bath. Basically, the entire printed product will be placed in a water based solution, and at the right temperature and agitation, the support material will dissolve, leaving the original design only. If the team uses this printer, then the AutoCAD design of AguaClara plants need to be manipulated less before printing because they do not need to be disassembled. Although this type of 3D printing can be quite expensive because you still have to pay for all of the support material, it is cost free at the Rapid Prototyping Lab.

When 3D printing a design, the object being printed should be meshed in order to accelerate the process. There are meshing commands that come with AutoCAD 2013 and 2014. If one uses the 3D modeling view of AutoCAD, they can gain access to the meshing Commands. Using these commands, AutoCAD can draw basic 3D shapes, including boxes, cylinders, and torus'. However, you cannot select an entire design of an AguaClara plant, which has different types of basic shapes, and expect AutoCAD to mesh the entire design properly. The second method the team explored was an AutoCAD Solid to Mesh Plugin. The only problem with this method is that a dialogue box interrupts the command line. Unfortunately, this means that this process can no longer be completely automated.

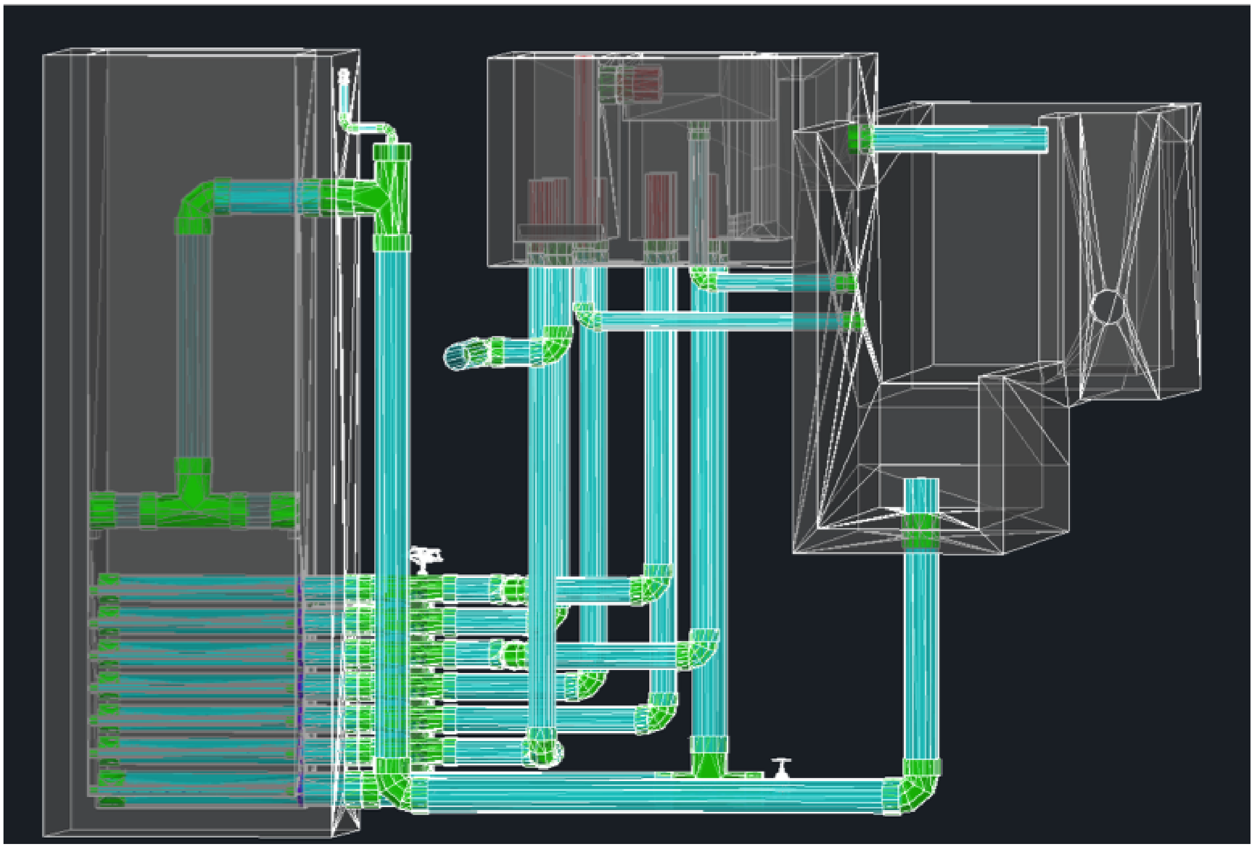

Figure VI: The MeshSmooth command in AutoCAD was applied to the entire design but the tanks were improperly meshed.

Discussion and Future Work

Future Small Scale Plant Model teams should consider the following as they progress towards automating the entire 3D printing process of small scale plant models.

MathCAD

There are multiple ways the team can mesh a solid. If the team were to use the commands that come with AutoCAD, they need to create new MathCAD design files, similar to the ones that already exist, but use functions like BoxFMesh, PipeFMesh, or ElbowFMesh, which would draw parts of the plant as meshes when they are first drawn, instead of functions like BoxF, PipeF, ElbowF, which draw the same solids unmeshed. Or, every time an object is drawn in the original design MathCAD files, there can be the same exact code that replaces the normal drawing functions with their complementary mesh functions. In this case, there will be double the number of stacks in the drawing file because there will be a normal solid stack followed by a meshed stack that looks almost identical. This may increase the file size by a significant amount that may impact the speed of the design server.

Another option would be to use the AutoCAD Solid to Mesh Plugin. This plugin can be downloaded at http://sycode.com/products/solid_to_mesh_ac/index.htm, off of the Sycode website. This alternative, costs $299. The commands that come with this plugin are useful because any number or type of solid selected can be converted to a mesh. The only problem with this method is that a dialogue box interrupts the command line. Unfortunately, this means that the printing process can no longer be completely automated. However, because the entire design can be meshed at once, if a 3D print file was requested, a team member can download the AutoCAD design for the desired flow rate and manually mesh it quickly.

Sizing

Another issue is scaling. The team needs to create MathCAD functions that can properly scale parts of the plant down. The printing limit of an Objet30 printer is 0.0011 inches and for a uPrint SE it is 0.01in. This means that pipes, including those used in jet reversers and the chemical dosing system, cannot be scaled down directly. So, if the plant were to be scaled down 1:20, like the current small scale model, the size of the smaller pipes need to be adjusted. In order to accommodate for the minimum printing size, there needs to be a MathCAD function in the ExpertInput file. This function should take the original diameters of pipes and wall thicknesses, and scale them down. It should also account for the possibility of the scaled down value being less than the printing limit. Perhaps in this case, the function should assign the printing limit as the diameter. Also, in the current small scale plant model, the walls were too thick. There should be an additional thickness conversion function that will make the plant wall thinner than the actual scaled down thickness. Finally, the baffles in the Flocculator and Sedimentation Tank will be too thin to print. Currently, these are made of paper that was not 3D printed. So, the team needs to figure out if they want to print the baffles or keep making them manually.

Also, it is important to consider which parts of the design to print together. The uPrint SE has a build size of 8 x 6 x 6 inches. Therefore, the Stacked Rapid Sand Filter and drain channel should probably be printed together, and the rest of the plant can be printed separately. It might be better for the chemical stock tanks to be printed out separately as well.

Presentation

There needs to be a base for this model. Perhaps the team should look into creating a base platform with cylinders attached to them. These cylinders, or pillars, can support the elevated parts of the plant, anything other than the filter. Perhaps shallow and hollow cylinders can be attached to the bottom of the plant components that so the the cylinders attached to the base of the model can fit snug in these hollow cylinders.

In the current small scale plant model, plexiglass is used to showcase areas of the plant that are often hidden by walls. In the past, the plexiglass was manually cut before being added to the model. There is no 3D printer that can print plexiglass. Therefore, the model can either have missing walls to display aspects of the plant that are often hidden, or someone will have to manually laser cut plexiglass for these missing walls. There also needs to be a MathCAD function that will delete certain walls for the purpose of presentation.