Technical Notes from experiences and studies in using Parametric and BIM architectural software.

Virtual Build Technologies 4-3-2007

The following are notes from our observations in working with CATIA Version 5 and Digital Project modeling software. We have used these programs in context and have come to the following conclusions of the realities of the software verses the marketing hyperbole:

Parametric Digital Modeling

Parametric digital modeling is the paradigm of programming the definitions of the geometry and their associated relationships so that they might be more easily adjustable by simple algorithmic manipulation and changes can be varied interactively. In theory, a well thought out parametric program can increase the productivity, allowing for an increase in design iterations and the creation of variations in families of parts for fabrication. It promises to increase the productivity of an operator, saving time in the design process. Our own experience and that of watching the implementation of these tools within Gehry Partners and customers of Gehry Technologies who purchased Digital Project has shown us that it has actually resulted in slowing project design and costly overhead increases, when compared to earlier process and tools that have already proved to be successful.

Unless hardware exponentially improves, say to an order of magnitude of at least ten times that of the current leading edge workstations, parametric modeling tools like CATIA V5 and Digital Project become extremely inefficient digital modeling tools on projects larger than a single family residence. Further, data management remains unimproved over earlier versions of CATIA and in many cases is even more onerous. There is still no “check in, check out” feature. Having stated this, it is still a tool worthy of being in the “tool box” if you will, able to be efficiently applied to very early stages of project development, especially in regards to iterative form finding.

Some architectural software programs apply simple parametrics to the geometry automatically as you model, as in the case of Revit. Other software programs require you to program the parametrics as you model, which requires a more sophisticated operator with knowledge beyond the ability to just model in 3D, as is the case with Digital Projects. For an operator to efficiently take advantage of Digital Project unavoidable relational modeling architecture he/she would have to anticipate all project directions before hand in order to program the geometries and their relationships to each other as you build them. So you must foresee the programming concept before you begin to model the geometry. It does not properly allow for creative discovery without the possibility for major model rework and huge loss of effort.

In analyzing the use of parametric digital modeling within the AEC industry and especially with regards to CATIA V5 and Digital Project, the following are some of the realities and issues we observed:

- When you model using parametrics you are programming following similar logic and procedural steps as you would in software programming. You first have to conceptualize what it is you're going to model in advance and its logic. You then program, debug and test all the possible ramifications where the parametric program might fail. In doing so you may over constrain or find that you need to adjust the program or begin programming all over again because you have taken the wrong approach.

- Once you think you have a working parametric model you may still find you haven't programmed a parameter of the geometry in a way that is adjustable to a designer's future request. A designer might say I want to move and twist this wall, but you did not foresee that move and there is no parameter to accommodate the change. It then unravels your program. Many times you will have to start all over again. Imagine trying to do this on a complex and fully integrated building.

- After all the time and effort of programming the geometry to where you think you have it right, you may find you still have to start all over again because the initial design concept has completely changed.

- Once you have your program working if anyone changes a parameter it could affect the geometry somewhere in the design that you didn't want to be changed. This occurs often and the change may not be detected until much later in the design phase, or even worse, in the more expensive construction phase.

- This also points to the fact that any operator using the model needs intimate knowledge of the parametric program that is written for that specific design. This logic knowledge is not easily transferred with the 3D model. In a sense the original programmer of the model then becomes the owner of the model. Many times if the program is too complex the original programmer is the only one who can work with it.

Marketing Hype

Gehry Technologies also markets parametrics function to the architectural industry as if it is paramount to the design process and something that works seamlessly for them. They have touted that Digital Project has the capability to fully program a complete architectural design so that, with ease, a parameter can be changed and all the associated geometries of a project can be updated to the final desired results. As Dennis Shelden, Director of Technology at Gehry Technologies mentioned in his published doctoral thesis, "Recent improvements in the user interfaces to parametric modeling applications, and the inexorable advances in computational power, seem to have finally brought applications of fully parametric modeling within the horizon of building construction applications." [1] The concept of creating a fully parametric digital model of an entire project to accommodate variable changes is just not efficient at this time with the current state of technology. This is theory and hyperbole, especially when trying to accomplish such an all encompassing function on a 32 bit PC.

Bloated Data Overhead

Another problem with trying to fully parameterize a building is that today's computers are not ready for the computational overload that occurs with the overhead to support parametrics. Parametrics in Digital Project/CATIA V5 adds a lot of overhead to the model data size. We tested and determined it creates nearly ten times the amount of digital memory storage required in comparison with the exact same model transferred into or built in CATIA V4. On some of the Gehry models that we worked with that were parameterized in Digital Project, the models became overwhelming and could not be worked with or manipulated in real time. The parametrics had to be stripped from the model to make it usable.

Associating the elements to one another through the design tree and carrying the parametric information in the database creates a large amount of overhead. Working on a theater in Dallas, Texas the structure alone grew to over 1.2 Gigabytes. Transferred back into CATIA Version 4 through SDNF, the same structural model was only 5 megabytes and far easier to work with. On a high rise apartment complex in Brighton, England, the façade was modeled with the concept of parametrically controlling the exterior skin with the windows as power copies and their penetrations to adjust automatically. The model grew to well over a Gigabyte. Just trying to move the model on the screen became a great effort. In order to even work with the model it had to be stripped of the parametric relationships and "dumbed" down. Parametric modeling

[1] Dennis Shelden, Digital Surface Representation and the Constructability of Gehry's Architecture, MIT, September 2002, page 91.

made this project model cumbersome and impossible to efficiently work in. Luckily, it became a non issue as the project was put on indefinite hold.

Accuracy

On a project for the remodeling of the Lincoln Center in New York City, Gehry Technologies, contracted by Diller, Scofidio + Renfro, modeled curved panels that were to be a layup of plastic laminated with thin wood veneer. In our extensive experience working with isotropic materials we knew that wood veneer would act much like metal yet more delicately. If the surfaces were not accurate the veneer would split or buckle much easier than metal.

We had tested the Develop function in Digital Project and found that is was inaccurate. It did not work like the develop function in CATIA V4 which we used on all of Frank's metal clad buildings in the past. When asked to become involved in consulting on the Lincoln Center project by the team that was to fabricate the plastic veneer panels, we were told the surfaces were coming from Digital Project. We then warned them at the beginning that they would have problems using Digital Project because of this inaccuracy with the software. The CTO of Gehry Technologies, Dennis Shelden countered with a letter stating their position with the software. He said, "V5 will perform a "best fit" of a surface to these conditions, producing an approximation that minimizes the internal twist of the surface."

That was the very point we were trying to make. The software produced a "best fit approximation." This application needed a very accurate approach, not software that approximates. In the end, the team decided to continue to use Gehry Technologies and Digital Project. The panels were modeled and the geometry was sent to the fabricator. One panel went through 10 iterations at a cost of $15,000 per attempt and took over a four month period because the geometry from Digital Project was not accurate and did not work. We eventually were asked to step in and help. That company will end up eating roughly $250,000 because Gehry Technologies experience and tools could not deliver as promised. Conversely, we produced the geometry on the first try and built a working panel in less than one day using CATIA V4. One half day of work could have saved them a quarter of a million dollars.

Additionally, it was found that the expert modeling team at Gehry Technologies claimed they could not get some of the curves of panels to align tangentially with the adjacent panel. There were gaps they noted as much as a ½". The reason given they said there was a restriction with the software that prevented the two adjacent panels from sharing the same geometry due to the design tree concept. The GT team asked that the fabricators accommodate this modeling error by forcing the panels together manually.

Productivity

With our experience of modeling in both CATIA V4 and Digital Project/CATIA V5 we find it takes approximately three to six times longer for production modeling tasks and iterations in Digital Project/CATIA V5. This seems to be substantiated with what is seen at Frank Gehry's design office today as opposed to the past. The modeling teams have three to six times the operators on projects or take at least three times as long to produce the geometry than what was used in the past.

Continued Development in the Aerospace Industry

These struggles in using this software are not exclusive to the architectural industry. The aerospace industry, the intended target market of CATIA, has had growing pains in adapting to the use of CATIA V5. Airbus began to implement it on their A380. There were a number of problems and fingers were pointed in many directions and for many reasons that resulted in a loss of $6 billion to the project.

Keep in mind, Boeing has been using 3D modeling for nearly twenty five years, and has been working on implementing parametric technology into their process for the past fifteen years. It has taken that long and is still not widely used throughout their entire process. Boeing has been using all the versions of CATIA from V2 through V5 for the past twenty five years successfully. They are successful in using this technology because of their years of hands on experience and pragmatic development of their in-house process and expertise. They have worked closely with Dassualt to customize CATIA V5 to their specific processes. V5 was designed specifically for the aerospace industry. But even Boeing has had its struggles both internally and externally to implement and optimize it for their design through fabrication processes. Many of their subcontractors who were efficient on CATIA V4 have struggled with CATIA V5 and Boeing has had to take on more of the work internally.

The design process of an airplane is different enough from a building that the design approach with CATIA V5 does not directly apply. A plane is broken down into design teams. Each team is responsible for its components and how they interface to the adjacent parts. For example, the landing gear team is not concerned about other aspect of the plane other than what affects the landing gear and where it attaches to the plane. Therefore the parametric models are strictly for much smaller assemblies and subassemblies, as in a landing gear assembly. There is no concept for parametrically controlling an entire airplane. It is simply not done.

Conclusion

We believe parametrically controlled digital modeling has it place in early conceptual design or in the massing stage of a project and also at the back end for manufacturing and fabrication, when warranted or efficient. When you think about it, parametrically controlled digital modeling works well for quick design iterations of a project allowing a designer to step through many “what if” concepts much quicker, increasing productivity. Once the design settles down you do not want to allow anyone to change the design on their own, especially when the model is issued to the contractors. At that point you want the geometry of the model to be locked. A mistaken parametric changed later in the process can have a rippling affect that if not noticed could become a great liability.

At the back end of the process once the 3D model has been given to the contractors and fully defined for CDs, parametric modeling has the possibility to work well in defining the iterative changes of individual details and families of parts taken from the fixed master model. Solidworks, also owned and distributed by Dassault Systems works very well for this. Zahner Metals became very adept at taking our CATIA V4 master models in to ProEngineer and detailing the secondary panel systems and connection parts. Many of the connections were similar yet different enough that parametric modeling helped to create different families of part types.

To implement parametric software in architectural design, a new breed of architects will need to be trained. They would need more rigorous discipline, not only in understanding three-dimensional geometry but also in the discipline of software programming and architecture. We will also need more powerful computers to crunch the exponential numbers that it will require. Personal Computer technology is just now beginning to implement 64 bit technology so there is hope. It is not for today, in our opinion, and it is not friendly to short deadlines