NCPTT97 Final Report

Development of Nonlinear Documentation Strategies for Incorporating Computerized Solid Modeling in Historical Building Survey

Grant Number: MT-2210-7-NC-015

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1. **Institution:** Texas A&M University
2. **Project Title:** *Development of Nonlinear Documentation Strategies for Incorporating Computerized Solid Modeling in Historical Building Survey*
3. **Grant Number:** MT-2210-7-NC-015
4. **Amendments to Original Grant Agreement:** None
5. **Grant Product Descriptions:** The major project product is the project report of the development strategies for using solid modeling the documentation of historic buildings. Following this report are the electronic models created from these investigations and the data used to create these models.

6. / 8. **Work Costs Differences:** There was some money left over due to fringe costs differences for different students and changes in prices of some of the software and rental equipment.

7. **Work Cost Budget Breakdown –**

	Work Cost	Budget
Salaries for Field / Modeling work:	$5,939.39	$7,450.00
Equipment rental for Field work	$2,200.00	$2,200.00
Equipment / software for Field and Modeling work.	$1,431.70	$1,600.00
Indirect Costs	$3,750.00	$3,750.00
Total	$13,321.08	$15,000.00

9. **How did work advance the field of historic preservation:** Documentation is central to every preservation project whether it involves recording the presence of a structure about to be lost or preparing evidence for restoring or maintaining existing structures. This grant allowed us to explore how digital technologies like solid modeling can be used to either strengthen the quality of both the data gathered and presented during documentation projects and the methods by which that data is gathered and presented. It helped to shed some light on the problems encountered in transferring a technology like solid modeling that is designed for modeling conceptual structures to a discipline like historic documentation which needs to record existing conditions. It has helped to initiate the debate about the use of solid models as 3D transcriptions of our cultural heritage and stimulated further research initiatives in modeling techniques that also serve as documentation methods.

10. **Publication or Video:** A CD of project models and information will be forwarded by January 19.

Signed:
Date: 12/28/1998
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1. What is Solid Modeling?

1.1. Solid Modeling is a digital tool developed for the mechanical engineering discipline to automate the construction of rapid physical prototype models. The automobile, aerospace, and defense industries use physical models to help simulate conditions in their “real” products. Computer solid models make the creation of these prototypes more efficient because the digital models can be fed directly to Rapid Prototyping Machines that produce models without much extra human labor.

1.2. Specifically, solid modeling tools are software packages (data bases) in which 3D geometric entities can be created, stored, and related to other entities.

1.3. Solid modeling software can link non geometric material data like density, color, texture, Poisson’s Ratio, and Volume to solid entities.

1.4. Solid modeling software can calculate mass properties such as center of gravity, moment of inertia, and weight on individual entities and on assemblies of entities.

2. How Do Solid Models Differ From Other 3D Models?

2.1. There are two types of 3D models: solids and surfaces. Most high-end package allow the combination of the two. The differences are becoming less distinct as these combinations become more complex and as both solid and surface modeling tools develop.

2.2. Typically solid models are created from ideal primitives, i.e., rectangular solids, cones, cylinders, spheres, etc. These ideal primitives are combined through Boolean operations like subtraction, intersection, union, etc. to produce increasingly complex shapes. Solids may also be created by revolving, sweeping and extruding closed profiles along a path.

2.3. Surface models are created by stitching 2D surface elements together to produce a 3D shape. These surfaces are created from 3 point planar definitions. Surfaces are also created through NURBS (Non Uniform Rational B-Splines). NURBS are very versatile entities that can exist as complex surfaces or when closed they have properties like solids. Besides creating surfaces from an array of points surface models can be created from lofting and extruding curves, rotating curves, sweeping curves along rails, and connecting curves.

3. How Are Solid Models Currently Used?

3.1. Solid models as currently used in engineering applications are employed as digital prototypes of engineering concepts. These digital prototypes may be used to visualize appropriate relationships among various parts of a complex assembly or they may be used as the data that drives the automated construction of physical prototype models. Solid models are intended as front end concept generators and concept visualizers.

3.2. Solid models are also used in calculations concerning structural integrity and dynamic stability of complex assemblies.

4. What Are The Current Modeling Uses In Preservation?

4.1. Solids are used primarily as general visualizing tools. They are used to create basic 3D geometries of buildings and / or cities usually for context purposes. They are sometimes used for high detail digital renderings or texture mapping of existing structures but usually these efforts are accomplished through surfaces rather than solids.

4.2. Since HABS (Historic American Building Survey) does not yet accept digital models of any kind there is no current use of solids or surface models for documentation purposes. These purposes are filled by standard 2D drawings.

5. How Might Solid Models Be Used In Preservation?

5.1. Solids could be used as more contextually complete visualization aids of historic buildings and their contexts. Basic models of buildings could be quickly built and texture mapped so that the solid could be rotated on a computer and viewed complete with texture-mapped images of its existing conditions. The model would not necessarily be dimensionally perfect but the visual details of the building would be mapped on to the solid approximation making most models appear quite real.

5.2. Solids could also be used to construct the building in digital form from scratch by creating each brick, stone, or log, and placing it in its location. This use of solids can be very educational as it forces the digital builder to understand the structure of the building and the form of each of its modules. The disadvantage of this modeling technique for documentation is that it is quite slow when compared to 2D documentation techniques. It can also be quite difficult to form and present a building in its existing state because very irregular shapes can be quite difficult to model. This use of solids is better reserved for “idealized” detailed construction models that make no claim of representation of a building’s existing state.

5.3. Solids can be used in a way that falls between the two mentioned above. They can be used to build detailed 3D models of buildings in their existing state but without attempting to model each module exactly or the hidden construction materials contained within many buildings. This third use has some attractive features:

5.3.1. It requires more work than the idealized method mentioned first but it is mush less interpretive and thus theoretically better able to capture the true irregularities inherent in every structure. This method is most closely aligned with the current HABS standards of 2D documentation.

5.3.2. It is less work than the second option mentioned because it does not need to treat each construction module as significant. Thus a large expanse of a brick wall can be treated as a geometric entity and measured as such without concern for the exact placement for each brick.

5.3.3. For most types of homogeneous construction this method is able to provide information for structural calculations pertinent to its existing state.

5.3.4. This option is also the best option for producing research models for historical research. Ancient and medieval buildings typically have few if any written documents to support research on their design and construction. As the only source of data, the building provides dimensional clues to its past. Models built with this kind of accuracy can serve many researchers who are unable to visit the site now or who may be making a study of the building after it has been lost.

6. Solid Modeling Uses Considered In This Work

6.1. The work of this grant does not pretend to define a single methodology for all solid model applications in historic building surveys. The primary objective of the grant was “to create a measuring methodology linked to the operations of solid model production." Thus the third option above, one I call "near transcription" is the use in preservation for solid modeling on which this study has focused.

6.2. This study was proposed in 1996 for the 1997 -1998 academic year. The problem with proposing methodologies is that they can quickly become obsolete if the tools employed by that technology become obsolete. This study employed at least three technologies that are still very much in flux and developing rapidly. These technologies include surveying instrumentation like total station theodolites, 3D digitizers, and solid modeling software. Because of this condition, this study did not focus on developing a particular method linked to particular software or measuring technology, but it attempts to identify problems and recommend solutions raised by attempts to make solid models for the purposes of "near transcription".

7. Scheme Description

7.1. The original plan was to begin with simpler buildings and progress to more complex structures, refining the process as we went along. This process was followed in spirit if not by the letter. The change in building studies was due to access, availability, and student workers to aid the project. We began by examining the Goodrich house in Anderson TX. Our second project was to be the Temple Freda in Bryan, TX, with our final project being the Carnegie Library in Bryan, TX. The Goodrich House is a light framed house whose scale and low level of design detail made it a good project with which to begin. Both the Temple Freda and the Carnegie Library are masonry structures. The increased complexity of these projects rested in their greater scale and the increased complexity of their designed details. However due to renovation construction of the Carnegie Library and inaccessibility of Temple Freda these two projects were replaced by two projects within the larger single project of Abbey of Valmagne in Villeveyrac, France.

8. Project #1 Goodrich House

8.1. Introduction

8.1.1. The B. F. Goodrich House was constructed in 1850 in Anderson, Texas by Dr. Benjamin Briggs Goodrich. (Figure 1) The house is constructed with a wood braced frame with cypress clapboard siding and cypress and pine flooring. [1]The house sits empty and in extreme disrepair. Doors have fallen from their hinges, siding has rotted and separated from the walls and window glass is broken leaving the house open to the elements. The primary purpose for choosing the Goodrich house as a subject for documentation was that its scale was small making it accessible and it had already been documented by an earlier team from Texas A&M in 1994. Its small scale and the simplicity of its construction offered opportunities to explore the pitfalls of interpretation for historic building documentation, especially in light of the desire to utilize new tools for measuring and production. If one desires transcription then one must resist assumptions about perpendicularity and consistent radii, and resolve to document irregularities. This is the challenge for solid modeling.

8.2. Irregularities

8.2.1. In line drawings irregularities are limited in 2D to a plane and thus are no more difficult to produce for the patient draftsperson than a straight line. [2] For solid models irregularities are more troublesome but not impossible. Solid objects are produced by in many ways, but the primary method begins with an ideal form near the desired shape. It is not unlike a sculptor that begins with a large stone or lump of clay that is proportionally similar to the envisioned final shape though it is in fact a rectangular solid. By successive additions and subtractions of other shapes to the original form, the final desired shape emerges. Where irregularities in line drawings can be very nearly approximated in a plane without actually measuring the irregularity, for solid modeling the software needs to know something about the shape of the irregularity so that it can add or subtract that form from the original.

8.3. Solid Modeling Methodology

8.3.1. The interest in 3D solids comes from the interest in transcription. But current measuring methods were derived primarily for 2D representations and these techniques are not easily adaptable to creating solid models. For example; if one is hand-measuring a structure the field notes usually contain numerical dimensions on a sketch accompanied by textual information of important conditions. These notes must then be transferred to drawing programs to complete the 2D drawings.[3] The greatest problem with dimensional information from hand measurements is the insufficiency of dimensions alone to give unique position information. For this reason hand measurements are typically made from a datum line and restricted to a particular plane (horizontal if it is a plan, vertical if it is an elevation.)

Because the technique is 2-dimensional the resulting visual production is usually 2-dimensional. This makes hand-measuring inefficient as the primary data gathering tool, though it is invaluable as an error-checking tool.

8.3.2. A more suitable method for measuring in a way conducive to the production of 3D solid models is to use any tool that can produce 3D positional data. Typically this has been the theodolite or total station. This equipment has close ties to traditional 2D drafting but due to its increased digital capabilities it can also store information in 3D coordinate triplets (*x*, *y*, *z*).

8.3.3. Coordinate points are wonderful for position information but they do not have easily interpreted dimensional information, i.e. it's not immediately clear from the pair (5.2,22.1,3.4) (7.8,19.7,3.9) that the distance between them is 3.5735. However since these points are collected electronically, they can be loaded into a computer and placed directly into a model. One can then query the points directly in the computer to find the dimensional information.

8.3.4. The downside of this method is that the effort to make the 3D positional information more easily accessible creates problems for understanding the entity information. For example; we may take many measurements of the points on the elevation of the Goodrich house, but though they may be perfectly accurate in terms of their position, they are missing very important representational information. The fact that these points represent "window trim" gets lost. To utilize the positive characteristics of electronic survey "architectural" information must be conserved.[4]

8.3.5. With the Goodrich house we are then left with the decision of how extensively to use the theodolite coordinate data. If one measures all accessible areas completely with the theodolite, then one is faced with the task of relating the points in space so that they make architectural sense. (Figure 2)

8.3.6. An advantage of this form for the data is that it can very easily be manipulated in text editing programs to enable automated construction of computer models. It is important then, due to the extra layer of abstraction to find ways of coordinating the architectural information with the textual.

8.3.7. This can be accomplished in a number of ways: 1. Sketches and or photographs that contain points locations taken by theodolite, 2. Audio and video recordings of measuring sessions 3. Text entries into comment fields in data collectors. 4. Databases

8.3.8. Probably some combination of the above will be needed. We have found that sketches are often needed even when photographs can be taken simply

Because the sketch can abstract out all inessential perspective information contained in the photograph. This depends on the building. For the Goodrich house sketches were not used, but the previous drawings from the HABS team were. Photographs would have been useful too, but the drawings were detailed enough to mark points on and contained enough white space to allow for notes. The notes on the sketches contained key names which are matched as electronic entries into every electronic point stored in the total station. When the points are downloaded to the computer they are organized through a previously designed database which is customized to handle output from the theodoloite. (Figure 3) (Figure 4)

8.3.9. A point here about how the scale of architecture hampers the creation of architectural entities. Since setup time for a particular spot for the theodoloite is long, one desires to take as many points from that site that one can. This means that the order of point-taking will most assuredly not fall in the order needed for the creation of a so lid entity. However, database can sort the data in any manner necessary, so as long as the correct notes are taken and entered into the proper field at the time the points are measured they can be arranged for simple transfer to solid modeling commands.

8.3.10. To create solids one must then identify architectural objects to be created as solid objects. For most houses like the Goodrich house the object is a thin plane called a wall, roof, or floor. The irregularities in most historical houses makes regarding the wall as a single solid a gross oversimplification of the documentation problem. To break the wall into small ideal solid primitives would be possible but not the most feasible for the field work. Faced with the dilemma of measuring methods which are inconsistent with a truly efficient production of solid entities, one must decide whether to focus on developing new measuring methods or modifying existing ones to reach the goal of transcription. Our choice was to initially focus on modification.

8.3.11. Thus if the current art of measurement delivers 3D points in space[5] then the development should fall along the lines of how to better take these measurements and manage the information contained in these measurements.

8.3.12. Right away for the Goodrich house and for the subsequent project this meant that we would get to solid geometries indirectly through the creation of surfaces. Once surfaces are created we can then slice solids with these surfaces to gain solid geometries.

8.3.13. Now the measurement problem becomes one of interpretation and physical access. Without the aid of an expensive total station with a prismless distance meter[6] some parts of even the smallest buildings may be reasonably unreachable. However, if we add the methodology of close-range photogrammetry, it is possible ot accurately measure points we cannot acutally reach and use them in helping to generate the 3D model. We chose to merge the photogrammetry and the total station, by using the total station to provide accurate coordinate points. These points were used as controls for the points generated by photogrammetry. The software we used for the photogrammetry is called Photomodelerby EOS Inc. (Figure 5)

8.3.14. But saying you have a tool for solid modeling that can create solids of the resolution that one needs does not mean that it can be easily used as such. The problem in this case is not with the software but the nature of the subject. For any point to be located in space it needs to be recorded directly with the theodolite or it needs to appear clearly in at least two photographs. There is little guarantee that this can be accomplished given the site conditions and the location of the point. The point in question may be hidden from all views with the camera or the perspective may be so awkward that it is impossible to get a good differentiation between the two photos. Thus, even with Photogrammetry, it may be practically if not theoretically impossible to provide information on all needed points.

8.3.15. For the Goodrich House this was the case with the clapboard siding. The siding overlaps the plank below it so that the "plane" of the exterior wall is really no plane at all. Is it worth the time and effort to measure each piece of siding and its overlap or should one do as was done on the hand drawings, simply measure the average amount of overlap and present that in section? The problem with this method for 3D models is that the dynamic rotation of the model reveals its inconsistencies in 3D, where, since the 2D drawings are presented separately there is no obvious inconsistency.

8.3.16. The two choices we have to get around this issue is: a. to fabricate an "ideal" plank in solids and modify that according to the discernable corners of the piece given by measurement or to treat the exterior wall as a plane and reveal this information trough texture mapping.

8.3.17. We chose to treat the wall as a plane, although since we were concerned about transcription we would not obviously assume any verticality in the plane. The control points from the theodolite were all taken directly with the prism and thus register a "true" position in space.[7] From these points we can create surfaces in Photomodeler that represent local angularities in the wall. One caveat here is that due to possible errors in measurement the wall may then be introduced with angles that do not really exist. This is similar to the point in hand measurement that pulling an overall dimension can be more "true" because if one accounts for tape stretch and tilt then any sighting and reading errors only occur once rather than being repeated over many smaller constituent measurements.

8.3.18. Since the Photomodeler surfaces are polygonal faces they are unable to be used directly to cut solids. However, these surfaces can be used to draw surface curves that follow the tilt of the respective surfaces. With these curves, one can then enter another software program (Mech Desktop, Rhino 3D, Form Z, etc.) and use them to loft a continuous NURBS surface that can be used to cut solids.

8.3.19. With the exterior walls measured following the methods above the lofted surfaces created from these measurements are used to cut a very large rectangular solid block. The block is much larger than the house (the size of the site is fine). The NURBS surfaces are then placed in their measured locations and are then used to trim each side of the block. To make a complete trim the block needs to be shorter in the z direction than the measured walls. This difference can be quite small (.0001 in.) and thus kept to acceptable measuring tolerances.

8.3.20. The same procedure is carried through for the interior spaces on separate solid blocks. Once these blocks are complete they can be moved into their surveyed locations and then subtracted from the first large block. The result is an accurate solid model of the house without any window or door penetrations or roof.

8.3.20.1. The penetrations of the walls are easily accomplished by creating solid blocks from the measured data of the window openings and subtracting these block from their position on the overall model.

8.3.20.2. The roof is made by building two solid blocks from the dimensional information obtained through Photomodeler.

9. Conclusions from the Goodrich project

9.1. This technique is a bit strenuous for light-famed construction. In fact one might ask why one would attempt such a subtractive process for such an additive construction type, especially given that one of the pro's for using solids was so that one could obtain mass properties and perform structural calculations through Finite Element Analysis. Yet the alternatives are few. If the goal is to create 3D near transcriptions then the work is exponentially greater than producing 2D drawings. This occurs for a number of reasons.

9.1.1. 2D drawings hide surfaces. They choose the extent of the story they wish to convey and leave the rest alone. Producing 3D models means that all of the data must be collected from all major geometric entities in the building or you must idealize parts by copying them from other pieces or making assumptions about their overall form.

9.1.2. Irregularities in 2D drawings are easily interpreted without much error and without much added work.

9.1.3. The type and quality of construction determines the extent of the irregularities and thus the major effort of the documentation. Light frame construction tends to have more discontinuities than homogeneous construction types like masonry or concrete. Large numbers of sharp discontinuities pronounce themselves as "significant" for understanding the existing state of he structure. Less sharp irregularities like sloping or bulging walls, erosion or foundation movements that cause distorted but not broken surfaces are more easily handled.

9.1.4. Thus, though the scale of the Goodrich House and the simplicity of its construction seemed to make this an easier less complex starting point, it was, in fact more complex to model.

9.2. Boolean operations on Solid primitives are probably not suitable for our goal of near transcription but would be suitable for more idealized models. The various pieces of information may be measured on different days from different locations but the coordinate information retrieved from any electronic measuring device can be restructured in text files to create the solid entities. This means, for example, that if one were measuring an arch and were to assume that the curve of that arch was a single radius, then the radius and the profile of the arch could be measured from different points on different days, by different people and the information could easily be combined to produce the solid model. The process of measuring is thereby nonlinear because it isn't necessary to measure the way one would draw in 2D. This is taken up in the next project.

9.3. As we will see in the next projects lofting curves to create solid objects is the method that holds the greatest promise for all of the current electronic measuring devices that output coordinate points in space.

10. Project 2 Buttress No. 1 South, Abbey of Valmagne

10.1. The first south flying buttress at Valmagne is an excellent choice for our next investigation because it is a single object which lends itself better to Boolean operations. It contains enough design detail to provide some measuring problems and it is aged and warped to the point that it is impossible to settle for an idealized version. (Figure 6) One of the key interests for this buttress is the fact that it has failed, thus requiring an accurate digital reconstruction so that its structure can be analyzed.

10.2. There are many ways to build a model of this buttress but I will describe three ways and their associated links to measuring.

10.2.1. Lofted Curves.

10.2.1.1. Because the buttress contains rectangular, circular and angular elements all of which intersect at some point, it is best to decide how the lofting will occur in each of these segments so that appropriate measurements can be taken. Since this buttress has failed it is actually easier to just take horizontal measurements at the mortar joints to produce each curve. (Figure 7)

10.2.1.2. **Note:** Some software does not allow the curves to contain points outside of a single plane. In this case it is necessary to take special care to limit all points in each curve as closely as possible to one z value. This can be done with a laser level or string line. The actual z coordinates are then adjusted in a spreadsheet to have the same mean value before lofting begins.

10.2.1.3. Instead of measuring the edges of the object as one would do in 2D drawings, one measures “horizontal curves around the object. It is not required for the curves to actually meet at the corners but it is helpful if they do. (picture) These curves are then lofted into a solid object.

10.2.1.4. **Note:** The method of measuring these curves is irrelevant to the success of the model production though certain methods will make the production link smoother. We used a combination of methods. Where we could measure points with the total station and prism we did so. For producing curves at heights that were unreachable we used photogrammetry.

10.2.2. Surface by edges

10.2.2.1. One can produce NURBS surfaces by defining edge curves and then connecting these curves with surfaces. This method is obviously more linear than the previous and for many objects produces very nice results. One can essentially draw the object with a Total Station or with Photogrammetry and then use those lines to create the curves which in turn create the surfaces. The drawback for this method is that the surface is assumed to be a smooth transition between the curves. For planar objects this is fine, but for complex surfaces it is not. The same edges could define an infinite variety of surfaces. Since the buttress is planar on all sides, the curves defining the edges will account for any tilt, shift, or rotation in the plane but not for bulges or creases. (Figure 8)

10.2.3. Boolean operations

10.2.3.1. Since we are trying to produce near transcriptions the Boolean operations will be complicated. We will stretch the category of Boolean operations to include extrusions, revolutions, and sweeps. With these tools the modeling is made simpler if not solely Boolean.

10.2.3.2. A good approximation to near transcription can be gained through measuring edge curves and extruding them the width of the buttress. Since the drip molding detail dies flush with the face of the buttress the extrusion will include the molding. Once the main body of the buttress is complete the next task will be to model the buttress arch. This arch is a combination of a rectangular box, half octagon molding and an arch. The arch is measured with three points to get the radius. The octagonal section is measured linearly by total station. The rectangular box is measured by marking the intersection of the flyer with the main buttress, a point where it ends, and the thickness of the flyer. The octagonal section is revolved through the radius of the arch. A solid disk is then created at the radius of the arch plus the thickness of the octagonal section. This solid is subtracted from the rectangular box and the revolved octagonal section is connected to the box by union.

10.2.3.3. To take the Boolean model to the near transcription level would require many more steps than those just given. It clearly isn’t the most efficient or even the most accurate.

10.2.3.4. Though there are many other ways one could build this buttress they would not necessarily meet the near transcription goal. Lofted curves prove to be the most promising method of creating NURBS surfaces that can be used to cut solid blocks. It should be noted that this method is suited to current relatively affordable electronic survey technology. There is new pulsed-laser technology that produces thousands of point locations per second and essentially scans the object needed creating a surface. Lofting doesn’t make as much sense in this case, although it could help fill in missing details that these scans might miss. These pulsed-laser machines are $150,000 to $200,000 dollars which is clearly out of range for most preservation work.

11. Project 3 Piers at Valmagne

11.1. Medieval piers can be very complicated structures especially if they are considered in concert with the vaults they support. Piers are complicated because they are very complex in detail, large in scale, and accuracy is very important to understanding how they operate due to their combined structural and aesthetic function. The typical method for understanding and documenting piers is to cut multiple sections and display these sections together in a single 2D drawing. When measured by hand and drawn by computer a pier may take from 2 to 4 weeks to complete. Creating solid models was very difficult in the past because the complexity created very large digital files and the data which was taken by hand was very difficult to translate into 3D.

11.2. The difficulty of measuring piers has been eased somewhat by new technology. Total stations can make measuring points faster but because the piers are cylindrical setup times and checks for location accuracy can take quite a long time. Boolean functions do not make much sense on such complex structures so the preferred method is again lofted curves to create NURBS surfaces that can cut solid blocks. Hand measuring techniques and total station methods are consistent with the desire to produce section curves. Photogrammetry could be used and is quite valuable for gathering data to be processed away from the field. We decided to use a 3D digitizer from GTCO called their Freepoint Digitizer. The advantage is that this machine produces coordinate values like the total station but has much shorter setup times.

11.3. The Freepoint digitizer is an acoustic device that creates coordinate triplets by measuring the time it take a three receivers to pick up a sound emitted by a probe pointing to the desired point. The calculations of coordinates are done immediately and can be fed directly into a modeling program. The digitizer has an 8’ x 8’ x 8’ measuring envelope but it can be moved with the new positions tied to the original setup.

11.4. The process was to produce section curves that could be lofted and this proved to be very accurate and very efficient. (Figure 9) Most of the difficulties encountered were due to idiosyncrasies with the instrument during measurement rather than during model building. The digitzer helped to create full 3D models of piers in 4 hours instead of 2 to 4 weeks. (Figure 10) We tried to create the same model by sweeping vertical profiles along a single base path but all of the software we tried were unable to successfully handle the complexity.

12. Summary

12.1. Purpose for Using Solid Modeling for Documenting Historical Architecture

12.1.1. Near Transcriptions - Accurate solid models can give greater access to historical buildings by being visually and dimensionally accurate. Near transcriptions are “as-is” models of existing structures that provide the advantages of solid entities but limit the amount of idealized assumptions found in purely visual models of buildings.

12.2. The current state of the art in electronic survey technology obtains coordinate values for points in space. Building near transcription solid models requires creating methods for managing this information. The methods may change slightly depending upon the nature of the object to be documented and the survey tools but there are some basic techniques that are common to all.

12.2.1. Sketches and photographs of the intended object. Managing sketches is important. They must be accurate enough to understand the object and the context of each point that is measured. Photographs are very helpful in aiding understanding of sketches. Sketches should contain information that ties to the electronic data files. This can be a description or unique name for each point that is linked to a unique point number. Point names are important because they help identify the relation of one point to another. Simply relying on point numbers will confuse modeling efforts.

12.2.2. In 2D documentation points are usually taken in the order that they will be drawn so proximity in the text string is often the greatest key. In solid modeling the points often cannot be taken in the order they need to be used for modeling so a database is invaluable for creating that order. Databases, when properly setup, also allow for modeling techniques to change easily because the points can be rearranged easily.

12.2.3. Understand the data structure of the surveying instrument and create the structure of the data base so act as a link between the needs of the modeling program and the capabilities of the survey instrument.

12.2.4. No single software is capable of handling all documentation requirements. Software like Rhino 3D is very good at modeling but like most good modeling programs is perhaps not as good as a program like AutoCad in handling point data input. AutoCad, not being a truly flexible modeler can be used then as in intermediate step to further modeling. Most people have their favorite software packages but in this effort we have found the following packages useful in a variety of ways.

12.2.4.1. AutoCad for data input, manipulation, error checking, and project engine.

12.2.4.2. Softdesk Civil Survey Suite for organizing and downloading survey data from electronic data collectors.

12.2.4.3. Mechanical Desktop by AutoDesk for cutting solids with surfaces and parametric trials in pier measurement.

12.2.4.4. Rhino 3D for modeling.

12.2.4.5. Photomodeler for modeling, data creation through photogrammetry, and visualization.

12.2.4.6. Microsoft Office Pro for its Access database, Excel spreadsheet, and Microsoft Word text processor.

12.2.4.7. Paint Shop Pro for manipulating and organizing digital photographs needed for photogrammetry.

12.2.4.8. Automanager View 2.0 by Cyco Inc. for organizing all CAD 2D and 3D models, digital images, text and data bases.

12.2.5. The following hardware was also crucial to the completion of the project.

12.2.5.1. Sokkia SET SE Total Stations for control points and data information.

12.2.5.2. Pentium 200, 133, 166 Laptop Computers for data organization and modeling.

12.2 .5.3. Digital , Video, 35mm Nikon, and Hasselblad Cameras for records, publication, and photogrammetry requirements.

12.2.5.4. Nikon Cool Scan slide scanner for digitizing photographs

12.2.5.5. Jaz Drive by Iomega for storing large image files and models.

12.3. Modeling Documentation Links

12.3.1. The most useful documentation method for “near transcriptions” was the method of measuring curves for lofting into NURBS surfaces. Since this study ended Autodesk’s Mechanical Desktop has added lofting to its parametric modeler, so that curves can be lofted directly into solids. I have not doubt that further transformation will occur with the pulsed laser technology that will allow very fast and accurate curves to be measured.

[1]Information about the B. F. Goodrich House was provided by the HABS Document set created in 1994 by Texas A&M.

[2]In fact, hand-drafted lines are irregular by nature. It is only with the advancements in computing and printing that we have come to expect “true” lines in drawings. This raises the issue of what counts as an irregularity. When we use milled lumber that looks straight we mean to draw it straight and disregard any small twists or dips or shrinkage. It is the case that we rarely measure each piece of siding in a house like this.

[3]Where appropriate these dimensions can be directly applied to a solid primitive but it is rare in architecture that one can easily pull all of the dimensions of a solid entity at one time. In the case of hand

measurements the dimensions of the solid object would need to be related together, though taken at different times.

[4]We have found that certain electronic means of automating this procedure could be developed but that it would take the luxury of weeks of preplanning the field experience due to the uniqueness of most architectural objects. Most field time is precious. Such planning and programming could be planned in to the project so that it occurred months prior to the actual field experience. Given the time spent trying to understand field notes after a project it might be well worth the expense.

[5]All of the state of the art machines like prismless laser theodolites, laser wands, and 3D digitizers all have outputs of point-clouds of 3D information.

[6]These machines are very expensive and typically have resolution problems when understood in the context of transcription. *For* example, Sokkia makes a distance meter that can measure distances without a prism at 1k within +/- 3mm. However, it is unable to distinguish differences in the surface that lie within a few centimeters of each other.

[7]The other option for the theodolite is to treat the wall as a plane and mark that plane by using three widely spaced points on the plane. These points would define a tilt to the plane but they could not show bends and movement within the plane.

Figure 1

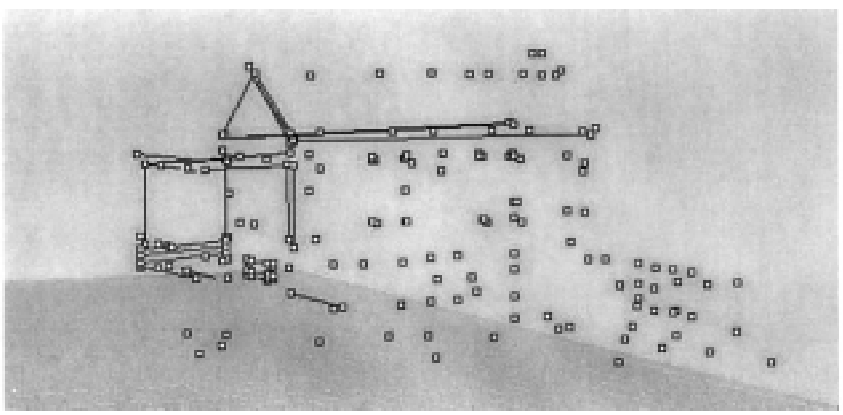


Figure2

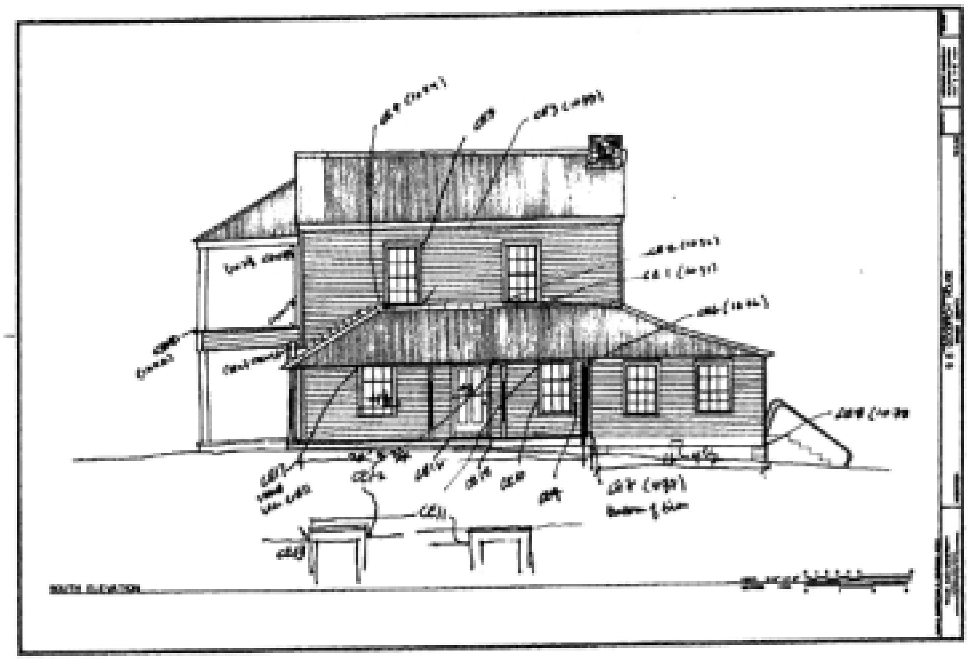


Figure 3

```
point,x,y,z,code
0001,0.000,0.000,0.000,ORIGIN
0002,0.000,38.349,1.951,2
1019,-35.426,27.214,9.605,S12
1020,-35.330,27.469,7.815,S13
1021,-36.364,37.685,7.569,CSW10
1022,-27.050,27.727,11.214,CSW8
1023,-35.732,27.094,11.795,CSW12
1024,-35.752,27.100,18.987,CSW13
1025,-35.535,20.501,19.343,SU1
1026,-35.107,14.034,19.253,SU2
1027,-35.040,13.961,13.169,SU3
1028,-35.271,17.580,13.196,SU4
1029,-34.939,11.583,19.664,SU5
1030,-64.335,47.334,-0.289,STN3
1031,-58.260,26.023,13.273,CE1
1032,-54.771,26.120,13.298,CE2
1033,-47.211,26.548,13.364,CE3
1034,-43.698,26.729,13.489,CE4
1035,-47.257,26.505,18.962,CE5
```

Figure 4

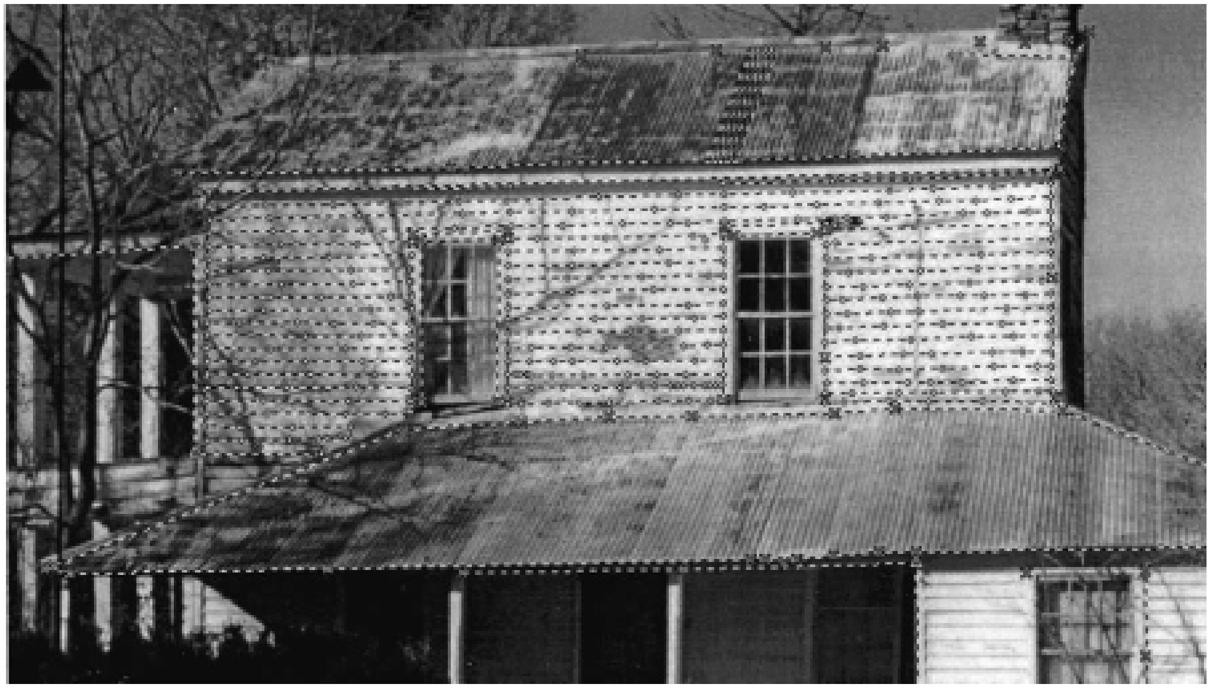


Figure *5*

Figure 6

Figure 7

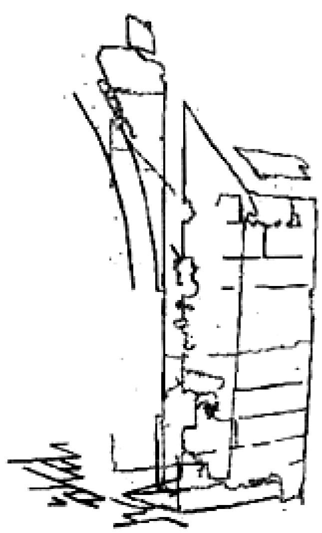


Figure 8

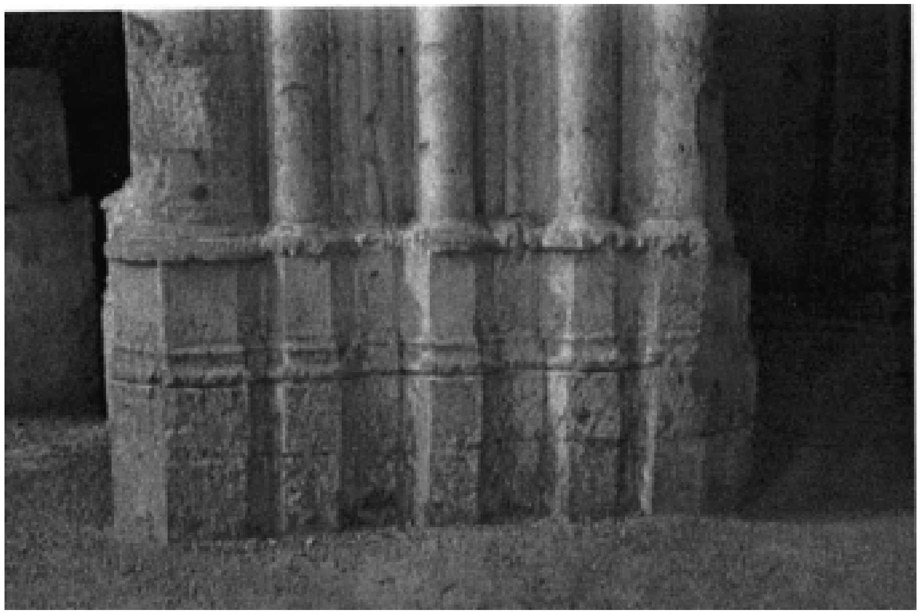
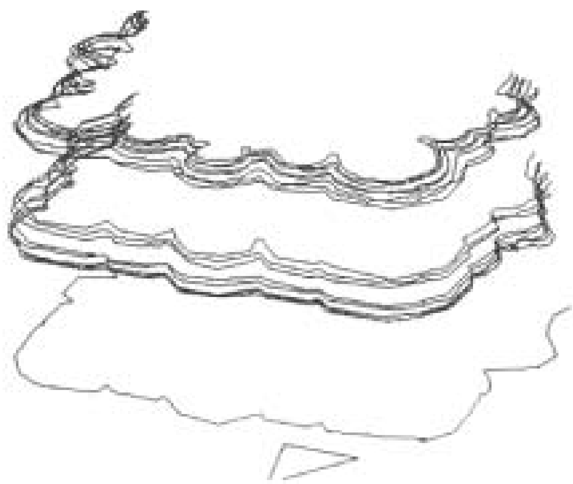
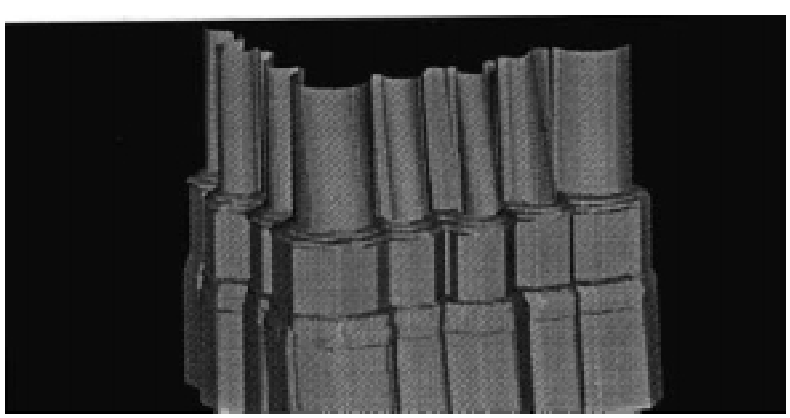


Figure 9



1 Figure 10



1 Figure 11