Point Clouds to Deliverable in AutoCAD® Plant 3D®
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PD2609  Point clouds continue to become a larger part of the plant engineer’s and piping designer’s workflow. This class will take you through the entire process from a trip to the field for scanning, through the scan registration process, and importing the scan data into AutoCAD® Plant 3D® software for design of needed deliverables. How do real world and design world, and brownfield and greenfield meet in the Autodesk plant space? What are some of the latest methods for going from cloud to intelligent plant object, detecting tie-in points, locating clashes, and creating needed deliverables all within AutoCAD Plant 3D? Come to this class and find out!

Learning Objectives
At the end of this class, you will be able to:

- Understand the entire journey from field scanning through design
- Recognize the advantage of Autodesk point cloud capabilities within plant design
- Learn Autodesk and Autodesk partner focused workflows for reaching needed deliverables in AutoCAD Plant 3D
- Use the tools needed to get from field to finish most efficiently

About the Speakers
Scott Diaz: Scott is managing director for kubit USA of Houston, Texas. Over the past four years he has managed the US headquarters office in Houston, Texas representing kubit software directly for the Americas while establishing a kubit reseller network throughout the US, Canada and Latin America. Scott has a background in business management and marketing with an MBA from Lamar University.
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John Bunn: John is technical sales and support manager for kubit USA. He has represented kubit for more than three years and is the top technical contact for the software in the Americas. John has more than 14 years of AutoCAD experience as a user and professional programmer with specialty knowledge in the industrial facility/piping design space.

Roland Legnon: Roland "Buddy" Legnon works on the Autodesk Plant Solutions Team. Buddy is an AutoCAD Plant 3D technical specialist and has more than 20 years of user experience in AutoCAD. His previous experience also includes time as a PDS and Autoplant administrator.
The Laser Scanning Process
Many people attending this class already have some exposure to the laser scanning process in general. While most have seen a point cloud before, not everyone has had the opportunity to understand the process of field data collection. This portion of the class will allow readers/attendees the opportunity to understand the full surveying/scanning process in an industrial setting.

For our trip to the field, our team is equipped with the Faro Focus 3D laser scanner, scanning targets (spheres) and a supporting tripod. The device uses phase-based technology which yields a high density result at a lower range distance. Density varies based on the user settings but can range from about 15 million to more than 100 million points per scan position. The scanner range varies based on environmental conditions but maximizes at 120 meters. Typically we use high quality scan data within 30-40 meters of the scanner position. The time per position varies based on the density settings and whether or not photographs are also collected in addition to scan data.

Scanner Setup
Prior to setting up the scanner in the first position, it is recommended that the surveyor perform a walkthrough of the area intended for data collection. The surveyor should assess the best possible vantage points for reducing the number of overall scan positions, while still collecting the needed data properly. The walkthrough will also help the surveyor visualize the area to be collected from each intended position. This is important when assessing scanner target positioning for quality registration results.

Setting Targets
Targets, as in traditional surveying, allow the surveyor to accurately tie each position to the next. At least three targets should be visible to the scanner, per scan position. The user should also
assess whether these targets are visible from the next intended scan position. Setting out scan targets is a crucial part of the initial scanning process for ensuring accurate data collection.

Our team used spherical targets provided by Faro Technologies. Alternate targets may include checkerboard targets or known surveying coordinates (tied to the Plant or global coordinate system). The Faro registration software (Scene) automatically recognizes these spherical targets and uses them to triangulate and connect each position to the next.

Spherical targets should be distributed at various elevations and distances from the scanner position. The surveyor should avoid setting targets in a linear fashion as this can impair the ability to calculate quality triangulations.

**Scanner Settings**

Our surveyor set the scanner at 1/5 resolution which yielded 28 million points per scan position. The scanner also has the added option of collecting photographs during the scanning process. Each of the two scans would take approximately 3 minutes to complete.
Moving Scan Positions
When moving positions, it is important that the scan targets (spheres) which were visible in the first position are visible in the second position. The scanner should offer a self leveling function as well as keep the settings from the previous scan. Once the surveyor is comfortable with the visibility and positioning of each position, the scanner is ready to collect data again. These steps are repeated to each position and new targets can be added as well.

Scan Data Registration and Pre-processing
Each scan position was recorded to the internal SD card on-board the laser scanner. Once all positions are complete, the surveyor is ready to take the collected raw data back to the office and import it into the scanner registration software.

Data Import
For our Faro scanner, each raw scan position generated an FLS file. We will use Faro's Scene software to walk through the scan registration process.

The team simply opens a new project inside of Scene and imports the collected FLS files. Upon first glance, it is easy to notice that all scans are stacking on top of each other. Because the positions are not yet registered, all scans are sitting at a 0,0,0 coordinate system and overlap with many similar points.

Pre-processing
Our next operation is to choose the "pre-process" option inside of Scene. Here the team is able to choose from a variety of scan registration methods. Since spheres were used in the field, this option is selected. The software knows the exact parameters of these targets and will locate them in each scan position. Based on the position of the spheres, the scan positions can be correctly oriented to one another.
The registration process will create our registered and correctly oriented point cloud. The accuracy report showed an overall standard deviation of 4 millimeters. When saving the project in Scene, we find a set of registered FLS scan files (now in the revisions folder) along with a project (FWS) file, which references each of the scan positions.

**Applying Color**
Once the registration process is complete, we can use the photographs collected to add color values. This process took about 1 minute per scan. An RGB value is assigned to each point on the cloud data.

**Bringing the Data to Autodesk Software**

**Creating Autodesk Point Clouds**
AutoCAD Plant 3D is used to import the native Faro scan data into the native Autodesk file format. Since 2011, Autodesk has provided the PCG file format for managing large point cloud data sets.

**Create Point Cloud**
To import the scan data into AutoCAD, we use the "Create Point Cloud" command found in the AutoCAD ribbon under the INSERT tab. Users may also enter POINTCLOUDINDEX into the
command prompt of AutoCAD. This allows the user to choose from a variety of scanner manufacturer file formats for import to AutoCAD. We find the Faro FLS and FWS formats for our purposes. After selecting each file, the user can choose to save the file to the desired location and the "indexing" process is started. This will convert the FLS files to the native PCG file format for AutoCAD. About 2 minutes passes before the scans are fully converted into the PCG format and ready to be "ATTACHED" into the AutoCAD drawing.

**AutoCAD Settings**
The POINTCLOUDATTACH command is used to insert the newly created clouds into AutoCAD. Some settings to be aware prior to import are the following:

- Many scanners collect data natively in meters. If working in imperial units, it is important to first scale your cloud within the POINTCLOUDATTACH interface
- Scan data does not function well, nor does it represent true intensity or RGB values in 2D Wireframe. A user should switch from this Shademode to any other available in AutoCAD
- Hardware acceleration should be turned on in AutoCAD. If a user is unable to turn on this mode, the machine may be lacking in video card quality and/or be in need of video card driver updates.

Now that the cloud data is successfully imported to AutoCAD, we can begin the process of extracting information as shown above. How is this accomplished? Please look to the next section "Shape and Data Extraction from the Point Cloud."

**Shape and Data Extraction from the Point Cloud**
This section explains how shape extraction algorithms, in combination with the proper catalog can help a user model and extract piping and structural data from the point cloud.
Piping the Point Cloud
Extracting piping from a point cloud calls for needed pattern recognition algorithms, should be catalog driven (based on standard piping design standards) and should create results which follow the guidelines of the final design software (Plant 3D) while staying as close to the as-built data as possible.

Shape Extraction Tools
Automatic shape extraction involves pattern recognition for standard objects. The most common shapes extracted are primitive lines, polylines, boxes, cylinders and cones. More specific extraction routines and algorithms may allow for specific parts (fittings, beams, etc.) to be detected within the cloud. The demonstration uses shape extraction algorithms from kubit to help close the gap between points and intelligent model.

Defining Patterns for Extraction (Catalog Driven)
Shape extraction is most efficient when searching for the best-fit of a pre-defined 3D object. What objects should we be looking for in the cloud? A piping designer should be looking for the same patterns that he/she uses for new design. These come from standard piping catalogs and specs already being used in Plant 3D.

In our demonstration, the kubit team shows how kubit PointSense Plant software will automatically import all of the user's current catalogs/specs from AutoCAD Plant 3D into the pattern recognition library. As a result, the software will now search for the same patterns that the user has familiarity to and would use for new design.

Locate Patterns on Cloud Data
Using kubit's "Walk the Run" routine found in PointSense Plant software, the user is able to step through a pipe run of a point cloud. Each component is detected along the line and the user can confirm or override the pattern recognition. This process applies standard components derived from the Plant 3D catalog to the point cloud data.

This process is meant to quickly and "locally" apply each pipe, elbow or inline fitting along a pipe run. Local pattern recognition is the first step towards a fully modeled pipe run.
Apply Design Constraints

After local pattern recognition with the "Walk the Run" routine, we notice small gaps between components and a lack of co-linearity between items. How can this be mended and why was this process necessary?

The aim of pattern recognition software is to help close the gap between point clouds and parametric objects. Design Software is made for Greenfield situations, not Brownfield. Such programs typically expect:

- Connected objects,
- Coaxial cylinder axis,
- Coplanar cylinder axis,
- 90° angles and
- Standard objects.

The following screenshots illustrate the need of coaxial and/or (at elbows and branches) coplanar axes:

After local pattern recognition of each object along a pipe run (lower left), we have to resort to or
apply the constraints of our target software (lower right):

During this process we want to stay as close as possible to the points in the cloud and apply as few changes as possible to individually modeled objects while still meeting the rules of the design software. Another important objective is that the sequence of our modeling actions must not have any influence on the final result. For example, if we begin the modeling of a long piperun with a very short cylinder fit along this piperun, the fitting of this initial cylinder axis will have a small error with respect to the full length of the pipe. Perhaps the pipe is bent or perhaps strong noise is present in the point cloud. As a result, every additionally connected piece will be inserted colinear to this first cylinder or at 90° angles with respect to the initial – short – axis of the first cylinder extracted. After a few meters or feet we get a noticeable error as seen in the figure below.

To avoid these troubles means we need an interactive workflow which include **global optimization** for an overall best-fit of all objects rather than following the constraints of the initially modeled piece. A Final result should resemble the model below:
An interesting observation: Modeling point clouds for Design software means to find a good tradeoff between geometrical accuracy and an easy to handle model which looks like the result of an engineer’s design process in a green field situation:

Create Plant 3D Objects
Pattern recognition has allowed for extraction of catalog components from the scan data and the global optimization has allowed for constraints to be applied to the design in order to meet Plant 3D guidelines. The data is ready for conversion to Plant 3D objects.

Generate Standard Plant 3D Objects
Although there are multiple methods for manually routing the Plant 3D objects over the detected routing line, the kubit team shows a completely integrated approach. PointSense Plant software will automatically create Plant 3D catalog components from the initially pattern recognized line. Within the "Export" section of PointSense Plant, the user can simply select “Export as Plant 3D Objects” and instantly have an intelligent Plant 3D model on screen.

Generate Isometrics
Now that the intelligent Plant 3D model is created, the Autodesk team provides automatic isometrics and/or orthographic drawing extraction. The “Quick Iso” routine was used to convert our 3D model into an isometric with bill of materials listed.
Structural Data Extraction

Structural modeling from point clouds requires very similar tools to piping design.

- Pattern recognition algorithms
- Defined catalog components (known standards, AISC, etc.)

The kubit software will supply the needed pattern recognition algorithms for recognizing steel members. The standard AISC steel catalog along with any user defined pattern can be extracted from the point cloud data.

Fitting requires the user to first define the steel profile desired for search. The user must then supply two points on the member. This supplies a search region for the software to begin the search for the desired piece. This process can be faster by performing a batch fit option from the kubit menu. A standard AutoCAD solid is derive with the proper centerline.
Locating Tie-in Points

If there is one thing we have learned from modeling and/or the intelligent modeling process, it is that post-processing efforts for generating complete models from cloud data can be very time consuming depending on the size of the project and level of detail. Often times a designer only needs to derive specific tie-in points from specific pipe runs in the field. Why model everything in order to extract a few key points?

Workflow options:
The user needs multiple options for deriving the tie-in points along a run. Based on the scan position, the user may only be able to see a flange or may only have scan data for the flange from a specific angle. For this reason, a software must allow flexibility in calculating the internal tie-in point.
Design Collaboration and Clash Detection

One of the most important uses of cloud data is comparing existing conditions with proposed design. In this case, a clash detection tool is extremely valuable. Fortunately, Autodesk provides this functionality directly in Autodesk® Navisworks® software. Please read the instructions below for performing clash detections between solids/surfaces and a point cloud.

Workflow options:
1. APPEND a DWG to Navisworks which includes both point cloud data and solids/surfaces of interest
2. Click the CLASH DETECTIVE icon in Navisworks which opens up two columns
3. On the left column, choose the point cloud data referenced in the DWG. Make sure that the clash setting is marked for POINTS.
4. On the right column, choose the solids/surfaces referenced in the DWG. Make sure that the clash setting in the column is marked for SURFACES
5. Set an appropriate tolerance for the clash searching between points and solids
6. Set the clash type to CLEARANCE and Run the clash detective
7. Visualize the clashes detected in Navisworks. You will notice the highlighted solids/surfaces which clash with the point cloud data within the desired tolerance set.