APPLICATIONS OF
3D LASER DIGITIZING AND SURFACING TECHNOLOGIES

Many companies have manufacturing requirements to copy or "reverse engineer" an already existing part for which there is no existing CAD model, print, pattern, or mold. In the past this process has been very tedious requiring weeks and sometimes months to complete. The engineer has to create a CAD model by measuring the physical part with calipers and/or a CMM and then create features and surfaces in CAD. If a 2D print is available, this data must be converted to define the CAD model features. This process is very prone to error and several iterations must be executed before an acceptable completed part is produced.

There is now an available process to support "reverse engineering" applications which greatly reduces the time to complete these projects, provides a complete and accurate CAD model on the first iteration, allows for the programming of tool paths, and is completely compatible with the company's current CAD/CAM procedures. This process includes the integration of the automated 4-axis 3D laser digitizing from Digibotics, Inc. with a complete software environment for point processing, surface generation, and analysis from Imageware. A case study using these technologies was recently completed by Fred Nicholas, CAD/CAM Manager, of InterMotive Technologies, a design and engineering company located in Belleville, MI. This paper describes the entire flow through the digitizing, surfacing, and CAD/CAM processes.

For this case study, Mr. Nicholas selected an automotive thermostat housing which is a part with some complex outer surfaces and an internal cavity. A core stick of the internal cavity was created. The Digibot II 3D laser digitizer from Digibotics, Inc. was used to digitize both the external part and the internal core stick. After editing the 3D digitized data, a point file was imported into the Surfacer software system from Imageware. Surfacer was used to create a network of B-spline curves and surfaces. An IGES NURBS surface file was created and then imported into several CAD/CAM systems to demonstrate the ability to create a surface and tools paths for making the part. For this case study, the Computervision CADDS5 software was used to demonstrate the complete CAD/CAM process.

The Digibotics 3D laser digitizing technology was used for this project because it offers several unique advantages for "reverse engineering" of complex parts. The Digibot II is an automated 4-axis digitizer that provides a simple, accurate, and quick way to copy or inspect complex sculpted surfaces. After fixturing an object, the user specifies a point density and instructs the system to begin. While digitizing, the object

rotates on the platter and the laser translates horizontally and vertically. Vertically spaced cross-sections are digitized starting from the bottom and moving upward. The Digibot Adaptive Scanning Software intelligently follows the contours of the surface acquiring a sequence of adaptively spaced points while keeping the laser beam normal to the surface. Concave surfaces and multiple contours are obtained by pivoting the laser about obstructing surfaces. After digitizing, the object is composed of a stack of cross-sectional contours. The entire object along with individual points and contours can be examined and modified as needed using the Digibot Data Editor. A surface mesh composed of triangular facets is generated by connecting points and contours between cross-sections. The resulting polyline and/or surface mesh can be exported via data formats such as DXF, STL, VDA, or IGES.

The Surfacer software system provides the link between the 3D laser digitized data and the conventional CAD/CAM system. Surfacer accepts point data directly from the Digibot Editor and performs point data analysis and processing such as segmentation, sectioning, filtering, and feature extraction. The NURBS surfaces are then quickly and accurately created from the selected point sections. The quality of the created surfaces are verified by points to surface comparison, reflectance analysis, curvature analysis, and cross-sectional tools. These surfaces can then be edited and/or modified. Point, curve and/or surface geometry can then be exported directly to "downstream" processes such as CAD, CAM, Analysis or Visualization/Animation systems.

The first step of the process was to digitize the thermostat housing using the Digibot II 3D laser digitizer. The housing was attached to the platter of the Digibot II by simply using hot glue. The Digibot II then digitized the entire housing by using Digibotics' patented adaptive scanning procedure. Both the external housing and the internal core stick were digitized. In a post-processing phase, Mr. Nicholas viewed the 120 cross-sections and performed minor editing to guarantee a good clean file of 3D data points. The digitizing and editing process for this housing was completed in 1 1/2 days. Mr. Nicholas also used the Digibotics Triangulator and STL Generation software to create an STL file of the housing. The Accelerated Technologies Inc. DTM rapid prototyping system was used to create a polycarbonate copy of the housing. This is very useful as an intermediate step to demonstrate that the digitizing process was very complete and accurate.

The two files of 3D data points (containing about 20,000 points) were then imported directly into Surfacer for creation of the surfaces. The two data files were first combined to form one complete external and internal object by registering the two

parts to a common axis through the centroid of the part. Surfacer provides a complete set of tools for aligning multiple scans or aligning scan data to CAD data. A "push-button" surface of the entire housing was then created. This one large complex NURBS surface is very useful for visualization, for gross product testing, and for interference checking with other CAD components. Because the Digibot digitized data is created in orderly well-spaced cross sections with no redundant or over-lapping data, this makes it much easier for Surfacer to create surfaces and perform its analysis functions. After the point analysis and registration, individual accurate surfaces were created. This occurs by generating surface patches over different point sections to define unique surfaces. Surfacer provides tools for detecting surface edges and segmenting points to define areas to be surfaced. Surface patches can then be fit to the points, with the user having control over the NURBS smoothness and fitting tolerances. For the housing, 21 different surface patches were created. These patches are stitched to create continuous, "watertight" connections, and different analysis was performed to confirm the accuracy of the surfaces. The 21 surface patches were then converted to an IGES 5.0 NURBS surface file for export into the CAD/CAM systems. This processing time in Surfacer took about two working days.

Mr. Nicholas then imported the IGES file into CADDS5 for processing. The file was also imported into ProEngineer and AutoCAD to demonstrate the IGES compatibility with other CAD systems. In CADDS5, a complete solid model was created by sewing the 21 individual surfaces. With this solid model, physical property analysis can then be performed such as volume and mass calculations. An STL file was created from this solid model, and a prototype was created using the 3D Systems rapid prototyping system. A tool path was created using Computervision's CVNC software. The internal cavity was first isolated from the external part for tool path generation. Then a tool path was generated on the external surface. Finally, a product drawing was generated for documentation of this part. The detailing environment included all radii, dimensions, cutting sections, tolerances, and information for placing the housing in its engine position. The procedures implemented in CADDS5 are very straight forward and utilizes the normal CAD/CAM functions that would be used for any solid model design. The procedures for CADDS5 were executed in two working days.

The processes that are demonstrated in this case study were not available one year ago. There has been tremendous progress during this time in the integration of the digitizing hardware/software and surfacing software for supporting these complex projects. This case study was implemented in about one week, and is at least a four week improvement over uses of other approaches. The Digibotics and Imageware

week improvement over uses of other approaches. The Digibotics and Imageware systems are the only hardware/software combinations that provide automated digitizing and surfacing of complete complex objects. This capability to recreate 3D objects with this process is available now for applications such as creating spare parts, recreating parts where no prints or CAD model exist, and creating a CAD model from a physical model done in clay, foam, or other fragile material.