Consortium to enable the sharing of Very Large Product Models for Manufacturing Applications

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Challenge and Impact

As the complexity of products grows more information is needed. New technologies such as additive manufacturing are on track to require extremely large volumes. This consortium will enable the sharing of Very Large Product Models so that new products can be defined and built.

Consider a cube one meter by one meter by one meter in dimension. Divide this cube into millimeter sections and imagine an additive manufacturing process in which each section contains an individual model designed to reduce mass, maximize strength and deliver system services (power, coolant etc.). There will be 10 ^ 9 of these sections [1].

If each section is described by a solid model boundary representation then one billion models must be read before the cube can be visualized, sliced or otherwise processed. This is because each solid will have a volume that is determined by the sum of its internal coordinates. There may be several hundred volumes in the billion that are as big as the whole cube. The processing system will not know which ones until they have all been evaluated.

Any Computer Scientist can list several methods to reduce the redundant evaluations. One of the simplest is to compute a boundary for each volume, store it with the data, and then create one or more indexes over the boundary dimensions.

The new consortium will agree on a set of indexing methods for the key applications and algorithms. These will include slicing, visualizing, picking and system tracing. We will define rules for dividing a large volume into partitions. We will create software to police the partitions and ensure conformance to the rules of the infrastructure. And we will create demonstrations to show that the new system is an effective way to create and process very large product models on the manufacturing shop floor.

As the capacity of manufacturing equipment grows larger, very large models are becoming more necessary. A single vendor cannot always provide the solution because multiple vendors are in the supply chain. In a simple example, one vendor may make the models, another vendor may slice them and a third vendor may use the slices to control the application of material. In a large application there may be many vendors depositing material. Yet another vendor may be responsible for detecting and preventing collisions. The new consortium will enable the required cooperation by defining the necessary resources.

Development Plan

There are many ways to model manufacturing data. One method is to develop an elegant little language and rely on user creativity to design solutions. Another method is to systematically determine the necessary and sufficient representations for all of the different information constructs that are being used in today's CAD and CAM systems.

The Standard for the Exchange of Product Model data (STEP) is using the second method. A STEP information model is written into a file by one CAD/CAM system and read from that file by another CAD/CAM system. Using todays protocols all of the data must be included in one file.

The STEP community has started developing a new edition of the STEP file format that will allow the data in a product model to be partitioned between multiple files using anchors, references and digital signatures. The proposed new format is currently being reviewed as a Draft International Standard ISO 10303-21 Edition 3.

http://www.steptools.com/library/standard/

In a two year program, the founding principles of the consortium will be put in place to enable the sharing of Very Large Product Models. We will complete the standard, define the first data organizations and create software systems to police the new rules. The subsequent development will follow the pattern established for the first application.

1. Select key applications. Data slicing for additive manufacturing will be the first key application. There are many others that are using product modeling technology such as tape layup, 3D circuit design, construction projects for airports and skyscrapers, and large defense platforms such as ship, aircraft and fighting vehicles. During the life of the consortium a team will be formed for each application.
2. Algorithm requirements. The algorithms for picking, slicing, visualizing and system tracing will be similar yet possible different for each of the key application areas. These algorithms will be cross referenced to determine what organization is required for the partitions in each of the domains.
3. Determine data structures. The algorithms will require information to be maintained to enable fast data processing. The teams will select the information that is to be written into the partition headers for each application/algorithm.

4. Create indexes. The header information can now be indexed to enable rapid access to those partitions that have a necessary quality. There may be multiple indexing methods.

At the end of the two year program the consortium will continue to develop and police the data structures of the first application, and move on to create additional data structures for manufacturing applications in aerospace, automotive, construction, metal forming, shipbuilding and other sectors.

Resource Availability

The members of the consortium will include:

- Rensselaer Polytechnic Institute to create the first policing software.
- The machine vendors to ensure seamless processing of the optimized models
- The CAD/CAM and STEP Tools kit vendors to make sure that they their systems can read and write the data organizations of the new partitions.
- The LOTAR organization to represent the requirements of the end users.
- Penn State ARL and Vanderbilt to create demonstration applications

Dr. Martin Hardwick will lead the project. He is a Professor of Computer Science, the President of STEP Tools, Inc., and the team leader of ISO STEP-Manufacturing. In his first role he has access to the knowledge and resources necessary to define and police efficient data structures. In his second role he understands how the CAD/CAM and machining companies are reading and writing information models today. In his third role he understands how product modeling is impacting manufacturing. It was this role that led him to start the Part 21 Edition 3 project of which he is currently the editor.

The table below shows how the resources map into the requirements of the five tasks.

In the second task the RPI students will be writing software to find and repair broken links, compare signatures with fingerprints, and validate the conformance of the contents of a partition with the information declared in the header of that partition. Work has already begun on this task and a library of open source software for partitioning a traditional STEP file can be found at the following web site.

http://sam-son.github.io/P21e3-Merge-Split-Tools/

In the third task software developed by the CAD/CAM vendors will be applied to very large models in the new infrastructure. The CAD Fix subsidiary of ITI has been developing software for additive manufacturing. STEP Tools has been developing manufacturing simulation software for very large volume removal for the DARPA AVM project. The CAD/CAM vendors initiated this project with their analysis of the data requirements of a one meter cube.

Two approaches will be taken to validate the infrastructure. Obtaining very large models is difficult because traditional CAD/CAM systems cannot make them and the 3D printing systems cannot process them. Therefore, we will first test the new methods by applying them to today's models. This will help us quantify the penalty of dividing the data between partitions and allow us to verify that all of the software tools are in place. STEP Tools, Inc. has several examples of STEP-NC models that can be used for this testing.

The second approach will be to create synthetic large models. This may be done by running a program to remove or add material from a volume using tool paths that have been generated at random.

Task	**Purpose**	**Resources**
1	Complete the International Standard for ISO 10303 Part 21 Edition 3	Prof. Martin Hardwick, LOTAR experts (Tom Thurman, Rick Zuray), Ed Paff of ITI
2	Agree on data organizations for the first applications and algorithms	Siemens NX (George Allen, David Madeley), Dassault CATIA (Jaques HEINISCH)
3	Write software to police the partitions and ensure conformance to the rules of the new infrastructure	RPI students using the software of the two toolkit vendors and others.
4	Write demonstration applications such as tiny cannonballs making cheese, giant 3D pong and the additive manufacturing of Manhattan	University student projects with assistance from the CAD/CAM and machine tool vendors
5	Determine consortia membership rules	All

The last task will determine the long term organization of the consortium. The Digital Manufacturing Foundation (DMF) has been established so that there can be a board of directors who will set the data sharing policies. The directors will represent the software and machining industries. The DMF's customers will be industry and government. When an organization wants to control some or all of its manufacturing from a large shared product model, it will approach the board of directors for a solution. For a fee, the DMF will agree on a set of data sharing principles, publish the specifications and create the policing software necessary to maintain conformance. The fees may be substantial when a leading organization wants to enable a new kind of factory automation with a new kind of sharing. The vendor/directors will decide if an enhancement has sufficient value to justify deployment, and then compete to provide solutions.

The new consortium will have a synergistic relationship with both ISO STEP and LOTAR. STEP and LOTAR will continue to represent end users by defining information models. The DMF will define fast data access methods to enable usage of those models on the shop floor.

[1] "*A Hybrid Geometric Modeling Method for Large Scale Conformal Cellular Structures*", Hongqing Wang, Yong Chen and David W. Rosen, ASME 2005 International Design Engineering Technical Conferences, Volume 3: 25th Computers and Information in Engineering Conference, Long Beach, California, USA, September 24–28, 2005.