Title:
Extending Model Based Definition to Capture Product Behavior and Contextual Information using a Model Based Feature Information Network

Authors:
Rosemary L. Astheimer, rastheim@purdue.edu, Purdue University Polytechnic Institute
Kevin Del Re, kdelre@purdue.edu, Purdue University Polytechnic Institute
Saikiran Gopalakrishnan, gopalaks@purdue.edu, Purdue University
Nathan W. Hartman, nhartman@purdue.edu, Purdue University Polytechnic Institute
Michael D. Sangid, msangid@purdue.edu, Purdue University

Keywords:
Model-Based Definition, MBD, Manufacturing Feature Information Network, MFIN, DMDII 15-11, Digital Thread, Model-Based Enterprise, MBE

DOI: 10.14733/cadconfP.2019.253-257

Introduction:
Computer Aided Design (CAD) software used to design mechanical parts continues to evolve and Product Lifecycle Management (PLM) processes continue to advance, but the transfer of data between mechanical designers and others in the enterprise, such as manufacturing, inspection, and product sustainment, has changed very little in the last 15 years. Current Model-Based Definition (MBD) is design product geometry centric, typically containing Geometric Dimensioning & Tolerancing (GD&T), annotations, Bill of Material (BOM) and limited processing information stored as Product and Manufacturing Information (PMI) [1]. Build data today is comprised of a combination of electronic and paper documents spread across many files and multiple formats, (i.e. PDF, HPGL, JPEG, STEP, IGES, ASCII, QIF, MatML, etc.). This assortment of delivery formats is not linked to the CAD geometry, making data transfer and design intent difficult to communicate and interpret. As a result, today's manufacturers must review, translate/interpret and/or re-enter the design data, causing their manufacturing processes to be labor intensive and prone to error [3]. In addition to the re-creation of the design data, significant amounts of sustainment data captured during the product lifecycle remains disengaged from both design and manufacturing. This full range of life cycle data can include material properties; design methods; analysis; manufacturing; measurement; inspection; certification test; field service; operations; maintenance; repair and overhaul data. This data is lacking meaningful connectivity to the digital thread, and access to this data is cumbersome at best. The reasons include both the complexity of the data models within which the data must be stored [3], and the absolute volume of new data, which is fast approaching Petabytes per year.

Main Idea:
The DMDII project addresses 1) the need for multiple data and file formats and configurations throughout a product's lifecycle, and 2) the resulting error-prone manual intervention that is required today to bring all of this information together. The MFIN technology innovation will allow industry to move MBD past geometry and 3D annotations to include other items in the product lifecycle such as, manufacturing planning, logical and functional behavior, and performance requirements to name a few. Leveraging this data throughout the enterprise will facilitate the automation of manufacturing planning and data retrieval and begin to remove the human-in-the-loop [2][5].

The project will innovate on many fronts including geometric representations, taxonomies and ontologies, metadata in the form of preservation descriptive information, data translation and certification, information schema, and storage media. The focus is on the digital thread [4] from design to manufacturing to sustainment with a feedback loop back to design, but the framework which will be defined will create a virtual or software linkage between CAD model features and related data elements in any data sets with the goal of creating a complete digital thread through a product's lifecycle. Figure 1 shows a graphic representation of the data flow.

With this framework is implemented, seamless digital data transfer between design, manufacturing, and sustainment will be realized, and error-prone manual transcription, translation, and human interpretation of data files will be greatly reduced.

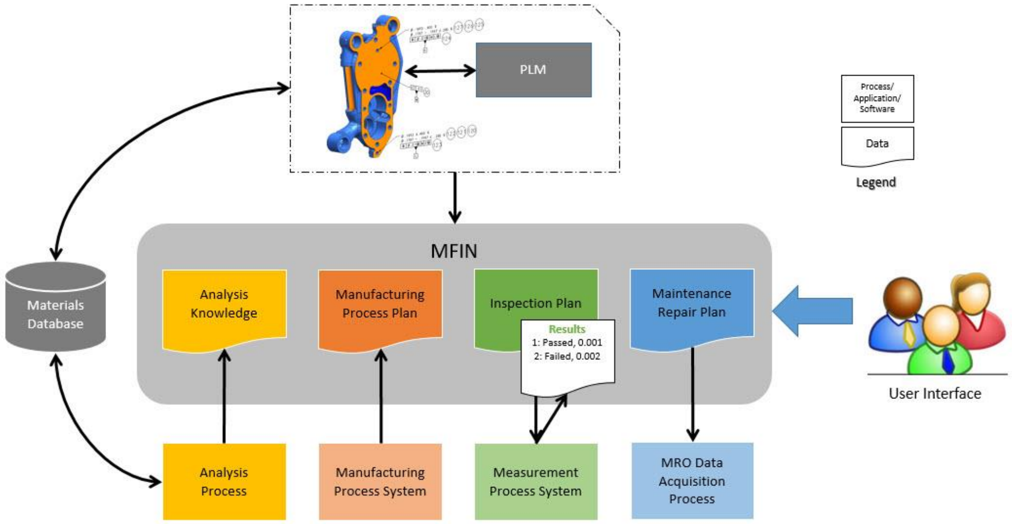

Fig. 1: MFIN data architecture diagram.

As additional information is associated with the MBD, the need for a comprehensive framework that will help facilitate standard methods of indexing, cataloging, storing, searching and retrieving the relevant information, as it is required across the product life cycle, will be evident.

The currently proposed framework, namely Model-based Feature Information Network (MFIN) has been developed using an Extensible Markup Language (XML) methodology by expanding the existing ANSI standard Quality Information Framework (QIF) for MBD. The existing QIF 2.1 standard successfully translates the MBD originating from a CAD tool to an XML definition and enables storing and retrieving metrology results tied to the features in a component [4]. MFIN extends this ability to associate data with the MBD at a feature level by creating linkages to other product lifecycle data such as material definition, structural analysis, manufacturing process planning, measurement and inspection, maintenance, repair and overhaul. These data elements originate from a suite of software and databases and are connected as the user deems beneficial. The MFIN enables maintaining mapping of the data with the features they belong to, throughout the lifecycle. This is achieved by developing the underlying MFIN XML Schema Definitions (XSD) with unique identifiers which dictate how the data elements are grouped within the XML model-based definition and Application Program Interfaces (APIs) for data exchange with software tools. For the chosen product lifecycle use cases, the targeted workflows have been laid out to enable data connectivity with the MFIN framework which are as shown below.

Material Definition Linking

In the material definition linking workflow, MFIN utilizes the PMI material notes associated to the part features [1] and enables creating associations to material records and properties from a material database tool to the part features. The material definition links created within MFIN allows material data access and retrieval in the downstream lifecycle processes and is shown in Figure 2.

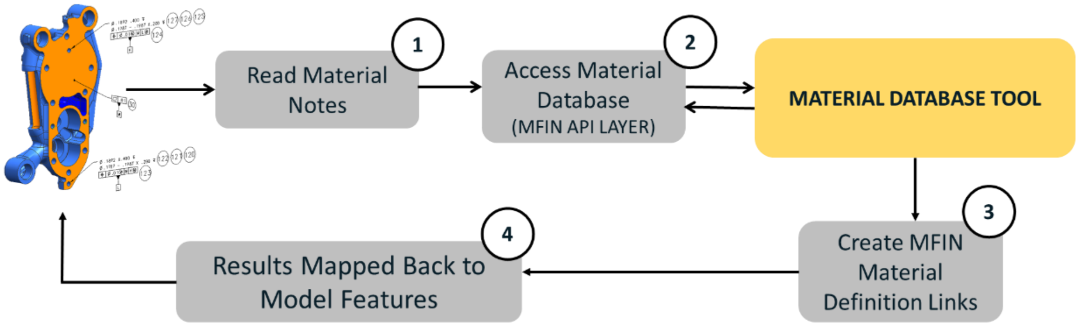

Fig. 2: Material definition linking workflow.

Analysis

Analysis workflow shown below describes the creation of associations from a CAE analysis tool to the Model-based Definition. The process involves importing the model geometry, extracting material definition links and assigning material properties using MFIN model definition to perform a structural analysis, as shown in Figure 3. The result files generated are grouped and mapped back to the model features for downstream data access.

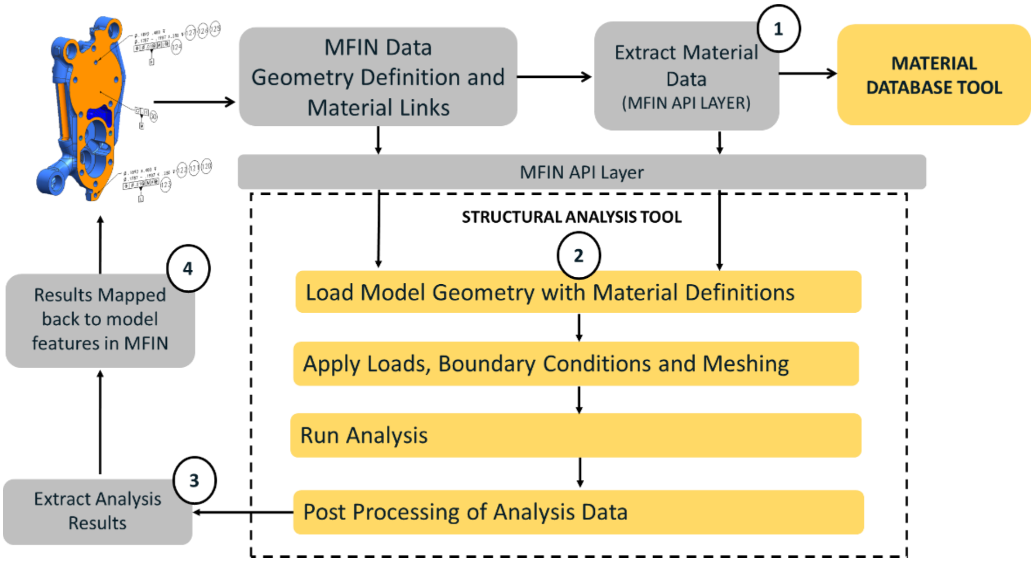

Fig. 3: Analysis workflow.

Inspection Measurement

The inspection measurement workflow shown in Figure 4 below allows the MFIN to store programmatically generated measurement programs and supply this information directly to a measurement system such as a coordinate measurement machine. The results of the test are then linked to the different geometrical features that are stored within the MFIN.

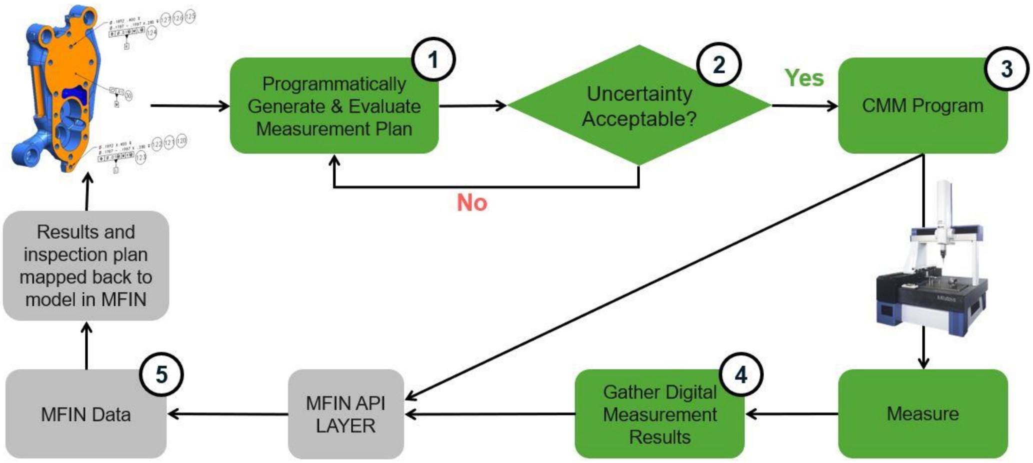

Fig. 4: Inspection measurement workflow.

Process Planning
The process planning workflow shown in Figure 5 below allows the MFIN to generate work instructions based off PMI present in the CAD model [1]. These work instructions are then linked to the MFIN to allow easy access.

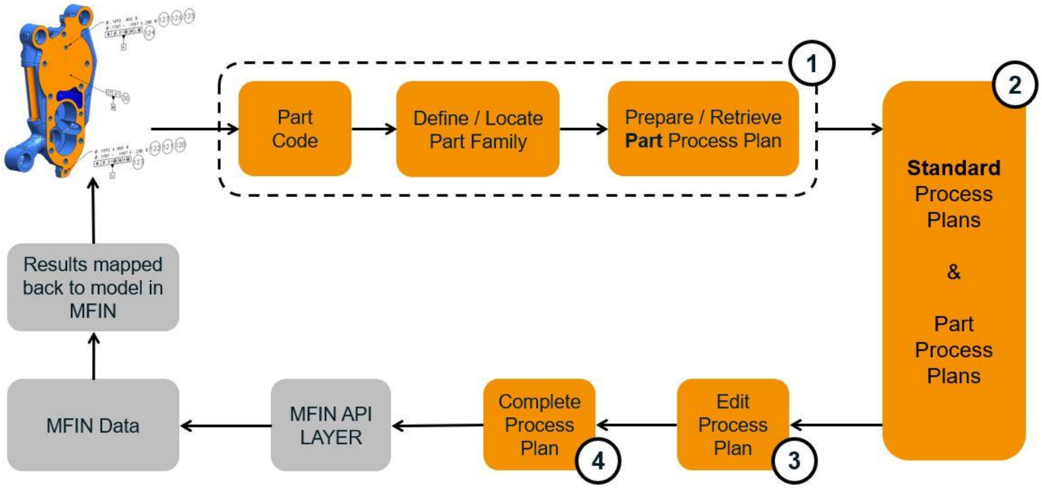

Fig. 5: Process planning workflow.

Development:
At the completion of the project, the team will have developed XML schemas for the four workflows shown above. The MFIN APIs developed will complete the linking of data from MFIN XML to external tools and databases in each of these workflows. The MFIN framework will be available to be leveraged by other systems such as Python, C++ and C# to allow connecting of the data relevant for that portion of the product's lifecycle.

Conclusions:
The presentation will be focused on introducing and explaining the goal of the MFIN and will provide an overview on how a few workflows in product lifecycle (CAE analysis, manufacturing process plan,

material linking, measurement & inspection, MRO) can effectively use the MFIN framework. A comparison to more traditional data exchange mechanisms will also be included, as the MFIN has the potential to substantially reduce losses typically associated with normal CAD/MBD data exchange.

Acknowledgements:
The authors would like to acknowledge the Digital manufacturing and Design Innovation Institute (DMDII) for funding through the DMDII 15-11-08 project, along with collaborators from Lockheed Martin Company, Rolls Royce, MSC Software, Capvidia, Granta, Siemens PLM Software, and PTC.

References:

[1] Camba, J. D.; Contero, M.: Assessing the impact of geometric design intent annotations on parametric model alteration activities, Computers in Industry, 71, 2015, 35-45. https://doi.org/10.1016/j.compind.2015.03.006

[2] Hedberg, T.; Lubell, J.; Fischer, L.; Maggiano, L.; Barnard Feeney, A.: Testing the digital thread in support of model-based manufacturing and inspection, ASME Journal of Computing and Information Science in Engineering, 16 (2), 2016. https://doi.org/10.1115/1.4032697

[3] Miller, A.; Hedberg T.; Zahner, J.; Hartman N.; Barnard-Feeney, A.: Towards identifying the elements of a minimum information model for use in a model-based definition, Proceedings of the ASME 12th International Manufacturing Science and Engineering Conference, Los Angeles, CA, June 4-8, 2017. https://doi.org/10.1115/MSEC2017-2979

[4] Morse, E.; Heysiattalab, S.; Barnard Feeney, A.; Hedberg, T.: Interoperability: linking design with metrology, 14th CiRP Conference on Computer Aided Technology (CAT), 43, 2016, 13-16.

[5] Quintana, V.; Rivest, L.; Pellerin, R.; Venne, F.; Kheddouci, F.: Will model-based definition replace engineering drawings throughout the product lifecycle? A Global Perspective from Aerospace Industry, Computers in Industry, 61 (5), 2010, 497-508. https://doi.org/10.1016/j.compind.2010.01.005