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SEAMLESS INTEGRATION OF LAYOUT AND SIMULATION

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ABSTRACT

This document talks about the usage of Simulation Data Exchange (SDX) (Moorthy 1999) in order to enable a consistent digital model of automotive factories. The scope of the digital model is to plan and analyze the factory by using different software packages. Thus the model doesn't exist in only one application. Therefore the consistency in terms of geometry and process data needs to be guaranteed with external support. Whereas any redundant information storage and rework of existing data has to be avoided. SDX is a promising approach to accomplish this interface management.

1 INTRODUCTION

The following paper describes a Proof of Concept project undertaken by the department of Information Systems and Services (IS&S) at the International Technical Development Center (ITDC) of Adam Opel AG. Adam Opel AG is a German Car Manufacturer since 1899. Since 1929 OPEL is owned by General Motors. ITDC is the main technical development center outside the U.S. Today the portfolio ranges from Luxury Cars to Small Cars, including Vans and Sports Cars.

To understand the concept of SDX at ITDC the Information Technology (IT) environment and the supported business processes need to be discussed first. The scope of this concept includes all assembly operations like Body in White, Powertrain assemblies as well as the General Assemblies and Chassis. Press/Die Engineering and Paint Engineering were not within the scope of this endeavor.

The planning, designing and analyzing of a factory involves various software packages. At General Motors Unigraphics® (UG) from UGS is used for vehicle and tool design. For Plant Layout, the FactoryCAD® tool from UGS that resides on AutoCAD®, and Architectural Desktop® is used. Workcell Simulations (WCS) that include robot simulation and ergonomic simulations/studies are done in IGRIP® from Delmia. Due to different levels of complexity and different areas of specialization of the software packages, Discrete Event Simulation (DES) studies are done in various tools. Currently in use at Opel, are AutoMod® from AutoSimulations and Witness® from Lanner. For those systems, which are not able to visualize a 3D model with a sufficient performance, the ProductVision® tool (also known as VisMockUp®) by UGS is used.

2 BUSINESS PRACTICE TODAY

The Plant Layout department creates a 3D model of the factory in FactoryCAD®. The engineers use FactoryCAD®'s smart objects and library objects wherever possible. For special machinery and equipment, simplified representations are used if no design data is available. Once the design data is available it is used to replaces the proxies. To present the model to their internal customers, a tessellated model is visualized in ProductVision®. The main task of this department is to guarantee that everything in the factory fits together from a geometrical perspective. In other words, Plant Layout department sees to it that there are no interferences, and that every item finds a place on the shop floor, while optimally using available space.

The Simulation expert is responsible for analyzing the same factory in terms of timing and output. He gets a paper drawing of the factory and starts to re-build the factory in the DES tool of choice. Information like cycle times, uptime/downtime, availability and routing information is then added. In order to achieve that, a lot of data needs to be gathered. Most often, this data cannot been found in one place requiring the simulation experts to ask the Process Engineer, the Tool Designer and the Plant Layout Designer. After all the raw data is collected, this data is assimilated and added to the DES model. The final step is to feed / program in the logic and run the experiments. The results are presented in tables and figures. For the internal customer to better understand the results the model is then shown in the native system (AutoMod®, Witness®).

WCS is a different type of simulation. The main focus here is reachability studies, interference, and collision detection. For this task the geometry data for both, the involved vehicle parts and the tools need to be present in the simulation package. Both these data sets are available as native UG files. Additional standard equipment like robots is available from the IGRIP library. In order to locate all items properly in the model, layout information is needed. This information can be imported from FactoryCAD®/AutoCAD® as a 2D background or reworked manually from a paper drawing. 3D Objects designed in FactoryCAD® can be used as well.

Another output of the WCS is a good estimate for cycle times. This information is given to the DES specialist. The result of the workcell simulation is a written report. For better understanding of the results the dynamic 3D model can be demonstrated in the native application.

3 DESIRED BUSINESS PRACTICE

In the desired business practice, as shown in Figure 1, every commodity would work in their application with the information provided by other departments available to them. For instance, the DES expert opens a project and finds the geometrical model developed by the plant layout department with process parameters like cycle time etc. entered by the process engineer. He or she may modify the default values, add the control logic and run the experiments. In this manner, there is no duplication of efforts, thus the DES specialist does not have to redraw the facility or reenter data values. The results will be made available as a report for all authorized users. For visualization every commodity is capable to present in the native system as well as in a high-end visualization package. This package should be able to handle the complete virtual factory in one model.

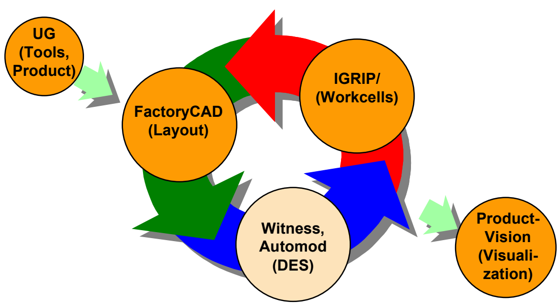

Figure 1: Virtual Factory Workflow

4 INTEGRATION STRATEGY

It is important to understand that the desired business practice requires a fairly thought-out IT-integration strategy. This integration can be achieved in various ways.

4.1 Object Oriented Integration

The term object oriented integration as used in this paper describes a solution in which each object carries all information and methods with it, thereby "telling" each application how to interpret its behavior.

For example, consider a conveyor that is represented graphically in 3D in the plant layout. When the same conveyor is ported to a DES system, it represents itself with parameters like speed, meantime between failure, meantime to repair, etc. and a 2D/3D representation. If this object is opened in a system for electrical design the wiring diagram will be displayed. This solution requires a high degree of standardization across many applications.

4.2 Application Integration

Application Integration implies that functionality and features from one application are available in another application. Container Systems and System Enhancements are two possibilities to achieve that.

- Container Systems: E.g. the plant layout is graphically represented in FactoryCAD®. FactoryCAD® could also be the container to run a simulation program from an external simulation application/engine by using its own graphics. Hence, the layout graphics does not have to be created again in a DES tool.
- System enhancement: A complete integration could also be accomplished by improving the graphical performance of a DES system in such way that the result is sufficient for plant layouts. Thus data exchange would be unnecessary.

Application Integration might be feasible for a pair of applications. But for multiple systems this solution seems to be unreasonable.

4.3 Data Based Integration

The premise behind Data Based Integration is that data which is relevant for more than one application is stored in a database. The database manages and synchronizes data between the applications. Alphanumeric data exists in tables associated with an object and is accessible by appropriate applications. Application specific data sets like CAD formats are expected to exist in parallel underneath the same object.

5 ROADMAP TO VIRTUAL FACTORY

From the authors point of view the object-oriented integration should be the long-term solution. As already mentioned a lot of work in terms of standardization needs to be done in order to accomplish that. Due to the complexity of the required integration in the given IT environment application integration is not a feasible solution. Data based integration is the most promising concept to achieve a seamless integration to enable the Virtual Factory in mid-term.

The process to develop a data based integrated planning environment follows three major steps shown in Figure 2.

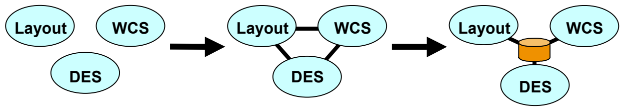

Figure 2: Roadmap to Virtual Factory

5.1 Step 1: Single Strategic Application Deployment

In order to integrate the applications effectively the number of participating applications need to be minimized. That means one application for one scope. The deployment of single strategic systems has been completed except for DES where two tools are used in parallel with an overlapping scope. (Refer Introduction).

5.2 Step 2: Build and Test Interfaces

The second step is introduction of point to point interfaces. This step is necessary to get the project immediately commenced and also to have a test environment. In this test environment IT solutions and their business suitability can be evaluated. The lessons learned will lead into requirement specifications for the final database.

As shown in Figure 3, three different categories of Interfaces exist between the applications. One category deals with geometry data and will be called as the geometry pipe. Native CAD formats like UG parts and DWG as well as exchange formats like DXF, IGES, etc. and visualization formats like VRML and JT belongs to this category.

Another category contains process information and will be introduced as the process pipe. The majority of this data can be expressed alphanumerically. SDX is a representative of this category.

Simulation packages provide motion graphics data. IGRIP®, AutoMod® and Witness® have their proprietary formats. Since it would make sense to exchange motion data between systems (e.g.: motion data of a robot with a DES tool), the motion pipe should be mentioned. Though one could consider VRML 2.0 as a known neutral format in this category, it is important to emphasize that the import capabilities of the applications discussed here are not mature enough to go into a test phase for motion data exchange.

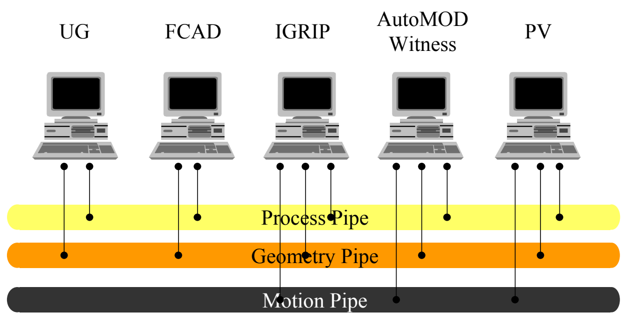

Figure 3: Data Pipes

5.3 Step 3: Integrating Database

In the third step a database should be linked between the Virtual Factory applications. This concept is not necessarily limited to CAD and simulation packages. Theoretically, every external system requiring access to these data can be hooked up. Only data exclusively used by a single application should be kept within itself. All data required by more than one application should be stored in the database.

6 PROOF OF CONCEPT

As the majority of data transfer for the Virtual Factory takes place between the DES tool and the Plant Layout tool, the proof of concept was done in this area. Thus, the geometry pipe and the process pipe were investigated.

SDX is designed to support two procedures. First, to initiate a set of data for the simulation expert to start from and second to enable non-simulation experts to run simple simulation models.

This proof of concept looked at how SDX could be used to initiate the simulation with an emphasis on how SDX can support “round-trip data”, in other words a seamless integration between FactoryCAD® 6.3 and the DES tools; AutoMod® 10 (Beta) and Witness® 2000 respectively.

Test data was taken from an ongoing project. Opel’s regular workforce created the layout data in 3D with FactoryCAD® and worked on the simulations. A separate team executed the proof of concept in parallel.

In order to export via SDX, data preparation was necessary, because in the normal business, process layout creation follows a different procedure. For instance, carriers and transporters that are created as dumb AutoCAD® blocks need to be assigned as the appropriate SDX objects. Also, station points on conveyors needed to be added.

The standard plant layout is an assembly, which contains numerous separate models sewn together by using the x-ref functionality provided by AutoCAD®. Therefore all x-refs needed to be copied into one file. Enhancements in FactoryCAD® 7.0 now render this procedure obsolete. Process parameters were added where default values were not sufficient. In order to define the material flow, pure simulation objects like sources and sinks needed to be created. Then the routing was set up in the SDX Route Editor®. The SDX Route Editor®, another software offered by UGS, is a graphical method to input assemblies and part routings. It uses a FactoryFLOW®database to store the route in. FactoryFLOW® is also a software offered by UGS in order to support material and labor balancing. This package is not in use at Opel. After completion of the preparation work the SDX file could be generated.

The concept of SDX doesn't require graphic data exchange between FactoryCAD® and the DES tool. All SDX objects can be represented in the DES tools with their native graphic capabilities as depicted in Figure 4. In order to synchronize corresponding graphics, mapping tables need to be introduced and maintained.

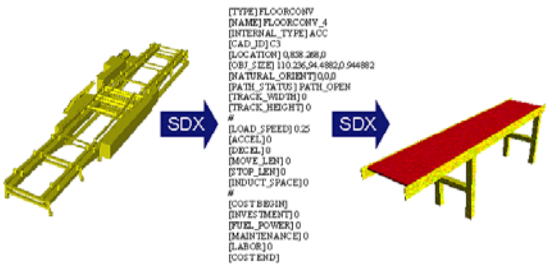

Figure 4: Mapping of Graphical Representation

This concept doesn't offer the same 'look and feel' in all applications and the model is incomplete because only selected object classes are transferred. In order to have the complete graphical model available in the DES model the graphic objects need to be transferred, properly located and synchronized. A simple way to synchronize is to reference the same data set as demonstrated in Figure 5. Both applications are pointing to the same graphical representation of an object. This file can physically exist in a database or in a file system. SDX can carry the 'pointer' to the file and the positioning information for the target application. Ideally every single object would follow this concept, because this offers the maximum flexibility

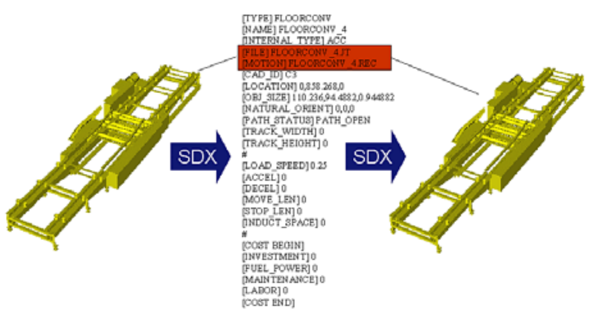

Figure 5: Referencing Graphical Representations

Witness® takes advantage of an external 3D-visualization tool. This solution is supposed to offer the capability to exchange graphics on an object basis. AutoMod® doesn't handle importing of graphic representations for all object classes. For example, for conveyors and electrified monorails, only native graphics are supported.

Thus, the proof of concept follows a compromise between the two exchange concepts. This is to merge all static data, like conveyors, machines, etc. into one exchange file and create one exchange file for each moving element, e.g. product parts, carrier, transporter etc.. The native graphical representations for the static objects in the DES tools overlay the 3D model but can be switched to become "invisible" for visualization purposes.

After some testing and reiterations with different candidates for the geometry pipe it was found that VRML seems to be the common ground for the participating applications.

The SDX file was imported in AutoMod®. The static VRML file was put in the background as a '3D carpet'. Movable objects are given their 3D representation by importing the corresponding VRML file. The Model was given to the simulation expert for further programming.

7 RESULTS

First of all it should be reported and acknowledged that the export/import of SDX and VRML from FactoryCAD® to AutoMod® worked. From a user's perspective, however, there is always room for enhancements. Some of the issues were addressed on short notice during the project.

SDX data exchange test for Witness®did not turn out very favorably. The issues were reported to Lanner and are under investigation and development, respectively (as of Q4 2000). The root cause might be a training issue.

The roundtrip could not be tested because both systems were not able to support it (as of Q4 2000). Though conceptual wise the re-import of updated simulation parameters like cycle time, availability etc. can be achieved easily and will be part of FactoryCAD® 7.0.

The concept of using the FactoryFLOW® database to define routing causes some difficulties and has some flaws. FactoryFLOW® and FactoryCAD® are carrying redundant information that is not synchronized. E.g. there are several ways to enter a cycle time. From a user point of view it is uncertain whose responsibility it is to enter the data in FactoryFLOW®. It is additional work for the Plant Layout designer and the DES expert would rather use his own DES tool to enter this information.

The initial simulation model given to the simulation experts saved them time because data duplication was not necessary. But for a one-time data exchange the savings need to be carefully evaluated against the additional efforts spent in Plant Layout. Usually the layout needs to go through numerous iterations before the detail and final equipment configuration is determined. The potential savings for an ongoing update of the DES model are obvious.

After doing the base simulation work of creating a model and run experiments the simulation expert usually cleans up the model and adds nice graphics in order to improve the show-room effect. This "non-value added" work could be drastically reduced. Additional automated routines for the sending and receiving application can reduce this effort even more.

8 FUTURE ENHANCEMENTS

As already mentioned; there is always room for enhancements. UGS and the simulation vendors did a great step to bring this development forward. However, three major areas of improvement shall be mentioned here.

1. In order to exchange graphical data most effectively with the highest degree of flexibility, the DES packages need to be able to import graphics on an object level for all object classes. JT is the tessellated format used in General Motors. Every additional tessellated format causes additionally IT costs e.g. for interface maintenance and disk space. So the capability to import JT would be the preferred solution. In order to support an object based graphic exchange, a routine in FactoryCAD® is required in order to parse single objects and move them into an object coordinate system. On the DES side a macro for the inverse process is required.
2. To take full advantage of SDX the roundtrip functionality is needed. This requires SDX read/write capability for all involved applications. Synchronization of object based parameters as well as routing information and control logic needs to be considered. The simulation expert needs to have the opportunity to control the change process. That means a change notification mechanism needs to be part of the interface.
3. SDX's business suitability at Opel suffers from an additional step in an external system. A graphical interface to enter routing information directly in FactoryCAD® without detouring via FactoryFlow® would improve the situation. This would also eliminate the redundancy of re-entering information like cycle times in the SDX Route Editor®'s database.

9 NEXT STEPS

The logical next step would be to go into a pilot project. But before this can be done, issues relating to scalability, robustness and performance need to be tested as well as the roundtrip transfer of data.

It is worth to evaluate the benefit of a SDX interface between IGRIP® and FactoryCAD® as well as IGRIP® and the DES tools discussed here. At the very least, object location, graphical representations and cycle times could easily be exchanged. When the motion pipe will be available and ready to use, as an interface SDX could support the synchronization between WCS and DES.

10 CONCLUSION

SDX is certainly a step in the right direction of seamless integration between Plant Layout and DES in order to enable Virtual Factory. It works under laboratory conditions but it is not ready to provide all the benefits, Virtual Factory is supposed to support in a productive environment.

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