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AN INTEGRATED APPROACH FOR AN EXTENDED ASSEMBLY-ORIENTED DESIGN OF AUTOMOTIVE WIRING HARNESS USING 3D MASTER MODELS

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Keywords: computer aided design (CAD), assembly, design models

1. Introduction

The automotive industry is changing. New derivates, worldwide production and shortened development times are only some challenges that have to be faced. The digital support of current development processes has to be advanced. By using CAD and new design methodologies, a lot of support and progress has been achieved throughout the last couple of years. Assembly-oriented design has become state of the art. The automotive wiring harness as an enabler of safety and comfort functions is getting bigger and bigger, its handling and release process is getting more and more difficult. As a result, new development methodologies have to be implemented. [Neckenich et al. 2015] have described in detail why there is the need for a change of the current process in automotive wiring harness development. Moreover, they have introduced the approach of using 3D master method as a digital support of wiring harness development. Every new methodology is based on a defined structure of models and has to regard the interaction between the used models. Out of this reason, we present an integrated approach for the extended assembly-oriented design of automotive wiring harness using 3D master models.
The rest of the paper is structured as follows: Section 2 gives a brief outline of assembly-oriented design including its methods of structural representation as well as general aspects regarding positioning methods. Section 3 refers to today's use of assembly-oriented design in the specific use-case of automotive wiring harness, which differs from other industrial applications. In Section 4 the new approach for an extended assembly-oriented design of automotive wiring harness is described, based on the findings of Section 3. The validation of the presented approach is described in Section 5. At last, Section 6 summarizes the paper and provides a short overview of future work on the topic.

2. Assembly-oriented design

Before one regards assembly-oriented design in detail, there is the need for a common definition of the contributed factors. Several definitions of assembly and product structure can be found in literature. We consider an assembly according to [Vielhaber et al. 2004] as "the sum of relations between two or more product components, i.e. an assembly is a product made up of more than one component". Assemblies themselves represent one kind of product structure, which is to be understood as "a hierarchical classification of the parts comprising a product" [Brière-Côté et al. 2010], including sub-assemblies, raw materials and parts. With top assembly, we always refer to the assembled elements that lead to the (final) product at the top level (see Figure 1). A model represents each sub-assembly, i.e. each assembly which is saved as a CAD file.

Most industrial products are assemblies: products which consist of more than one component. Their product structure contains several levels, each level representing a sub-assembly (often also called sub-module).

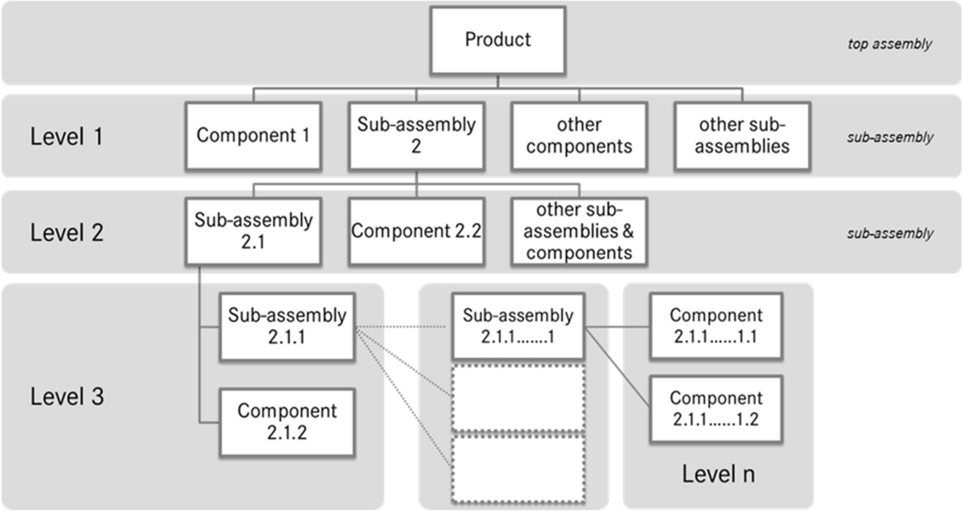


Figure 1. Product structure in assembly-oriented design

The sequence of the arranged assemblies and components inside the product mostly follows a logical order, representing, for instance, the inner relations between the parts [Hirz et al. 2013]. This is why the product structure itself is the main information source to extract the bill of material (BOM) for the product. [Brière-Côté et al. 2010] therefore define the BOM in parallel to the product structure.

2.1 Organization of product structures

Complex mechanical products are multileveled, i.e. they are made up of several sub-assemblies, which again consist of numerous sub-modules. Regarding modules, we keep to the definition of [Robert et al. 2011], who describe modules as an assembly of components, being "independent of the other modules". This applies to most cases as modules and sub-modules usually represent reasonable configurations of elements [Hirz et al. 2013]. [Li and Xie 2015] distinguish between two ways of modularization. Structure-based modularization which combines elements corresponding to their physical relationship is one possibility. Another one is function-based modularization, which groups elements corresponding to their function. Regarding the automotive industry, [Robert et al. 2011] provide three different ways of modularity. They differ between the "Modularity in Design", emphasizing the product architecture, the "Modularity in Use", emphasizing the customer requirements, and the "Modularity in Production", emphasizing the simplicity of assembling. Modularization of products enables an external product variety, by reducing the internal part multiplicity [Chu et al. 2014].

In most industrial applications, modules and assemblies, as well as sub-modules and sub-assemblies, can be regarded the same.

2.2 Methods of component positioning

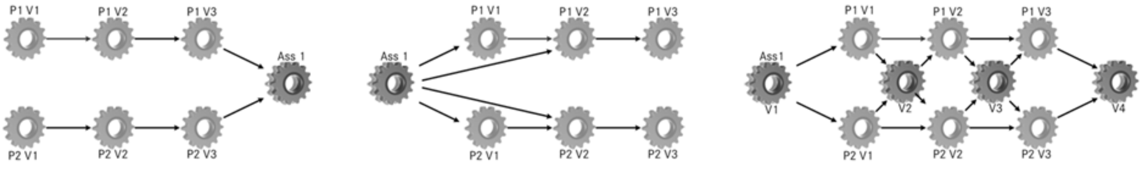
Today all CAD tools work in an assembly-oriented way. Assemblies and modules are used to group several parts or sub-assemblies. In order to build up an assembly, i.e. to position the elements inside it, different strategies are possible.

In small sub-modules, parts are usually assembled by the definition of geometrical constraints (for instance coincidence or offset conditions). This method, of course, gets complicated by including a lot of constraints when assembling to a multi-levelled product. Another possibility is to position all parts inside an assembly relative to a pre-defined main coordinate system. This coordinate system is usually the main coordinate system of the whole product, which is either the world coordinate system or a product specific main coordinate system. The positioning process inside the product is simple as all sub-assemblies are already positioned relative to the main coordinate system. The third way to position elements inside an assembly is the use of skeleton models. Specific geometrical elements inside the sub-modules (the so-called "skeletons") provide positioning information relative to another geometrical object inside a top assembly, which can also be the main coordinate system. All components inside the particular sub-module are positioned relative to the skeleton. [Hirz et al. 2013]

In automotive engineering, a combination of these three methods is used. In a full-vehicle assembly all sub-assemblies of level 1 are positioned relative to a main coordinate system. The inner structure of the assemblies is then made up of elements that have been positioned by different methodologies. [Hirz et al. 2013]

2.3 Methods for structuring products and components

Literature tells us about two different approaches to structure (sub-)modules inside a product: the top-down and the bottom-up approach. Having been on bottom-up assemblies, the focus in industry today is on top-down design, even though also mixtures of both are used (see Figure 2). According to [Amadori et al. 2012] the different methodologies originate from software development and "could be associated to analysis and synthesis".



(a) Bottom-Up Design (b) Top-Down Design (c) Mixed Design

Figure 2. Methods for structuring products and components (similar to [Vielhaber et al. 2004])

2.3.1 Bottom-up design

Using the bottom-up design methodology one starts with the definition of a single part, which is the focus of the approach. Parts or sub-assemblies that have a complex geometrical or functional representation have to be modelled first. From the low level to the top of the product structure levels the sub-assemblies are composed and built-up. The different elements lack a context dependency to each other, resulting in a complex modifying of the final geometry [Vajna et al. 2009], [Amadori et al. 2012], [Vahid 2016]. Elements are mostly positioned by using constraints. [Qin et al. 2011] regard bottom-up design as an implementation of "family-based product design through re-design or modification of constituent component of the product". [Vielhaber et al. 2004] propose bottom-up design "only on a solid product level concept", as they regard it as an obstacle for "design as a creative process".

2.3.2 Top-down design

Using the top-down approach, the holistic representation of the product is in focus of consideration. Starting from the required functionalities and basic conditions (high level conceptual models), the total structure, i.e. the division into granular sub-assemblies and base components (detailed models) for each level, is defined. It is an adoption of a "platform-based product design" [Qin et al. 2011]. In order to handle complex products, specific installation spaces are needed, providing a modular structure. Those installation spaces need to have well-defined interfaces to their adjacencies. The definition of sub-assemblies is then done inside the particular installation spaces [Vajna et al. 2009], [Amadori et al. 2012], [Chen et al. 2012], [Vahid 2016].

The interfaces between the models have to be clearly defined. This can be done by using different coordinate systems within the individual models or by positioning each model using the skeleton method [Vielhaber et al. 2004], [Vajna et al. 2009].

A specific characteristic of top-down design is that the product can exist without any detailed part definition. Furthermore, it provides a framework, in which top-level requirements can be transported down to the base level, although the mechanisms for data transferring in commercial CAD systems are still insufficient [Vielhaber et al. 2004], [Chen et al. 2012], [Chu et al. 2014].

2.4 Parent-child-relationships

The use of skeletons is the first step for parent-child-relationships and geometric transformations inside assemblies that are often managed by an EDM system [Vielhaber et al. 2004]. [Hirz et al. 2013] additionally distinguish between a "direct geometry derivation" and a "creation of geometry references". He refers to the skeleton method as an "implementation of adapter models". Using this kind of relation between parts and assemblies inside complex product models increases its efficient creation, although model stability decreases [Vielhaber et al. 2004], [Hirz et al. 2013]. The use of parent-child-relationships is founded on the "parametric-associative relationship of the relevant geometry" [Hirz et al. 2013].

2.5 Parametric models

[Stan et al. 2013] define a parametric model as "an intelligent part that uses parameters to drive the geometry". According to [Vahid 2016] parameters itself are "nongeometrical components" that control specific characteristics of a model. This enables an easy adjustment of changes.

The product structure, seen as an aggregation of elements within an assembly, is a static structure. All sub-assemblies and component parts are sequenced in a logical order. The model structure that describes a single component can also be considered as a static structure, "defining additional component sets on different levels of detail" [Anderl and Mendgen 1998]. As soon as parameters are added to the overall system, the model structure becomes a parametric system. Thus, its static structure becomes a dynamic structure. According to [Anderl and Mendgen 1998] "a dynamic model is created by defining a parametric (algorithmic) structure underlying the current instance of this model".

In general, there are two possibilities of modelling: direct modelling and parametric modelling. By direct modelling, parts are created without any parameters or references between the different stages. In contrast, by parametric modelling, elements are defined with a particular logic, based on geometrical, topological, physical or process parameters, which is saved in the model. Thus, a concrete instance can only be built when the parameters are defined, yet made concrete [Anderl and Mendgen 1998], [Vajna et al. 2009].

2.6 Summary

For describing assemblies and sub-assemblies in a product structure, several expressions can be used depending on the level of detailing. Modularization of products is essential to enable an external product variety. In most industrial applications modules and assemblies represent the same instances.

Positioning by geometrical constraints, relative to a predefined coordinate system or by skeleton models are three different ways of component positioning. The model structure can be done as a top-down, a bottom-up or a mixed design. Especially by using the top-down approach, there is the need for clearly defined interfaces between the different models. Parent-child relationships are another aspect of today's assembly-oriented design, often managed by a supporting EDM system. Parametric models are predicated on geometrical, topological, physical or process parameters, which change the static model into a dynamic model.

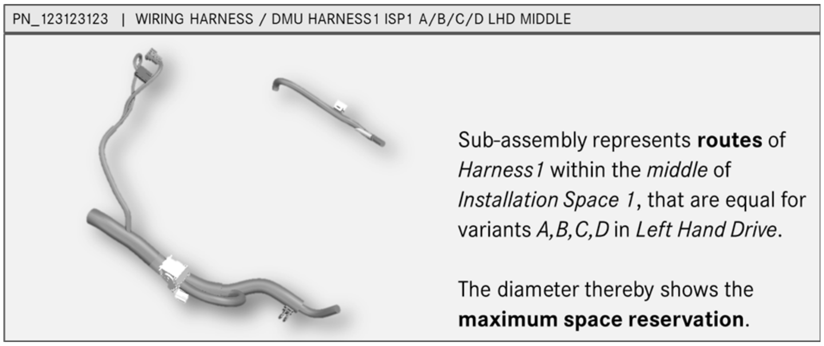
3. Assembly-oriented design in automotive wiring harness

Most designs in today's industrial applications follow the rules and corresponding aspects of the preceding section. A hardware assembly is represented by its CAD assembly, i.e. for each hardware element one usually finds an appropriate CAD model and vice versa. In contrast to those, the assembly-oriented design in automotive wiring harness is completely different. For a hardware module or a hardware assembly, there mostly is no corresponding CAD model. The sub-assemblies of the wiring harness are built together "according to the meaningful configuration in the relevant modules" [Hirz et al. 2013]. Consequently, modules and assemblies cannot be regarded the same in the context of automotive wiring harness. For this reason, we only focus on sub-assemblies in the rest of the paper.

As already mentioned above, harness as a product has no appropriate CAD model. In order to show the harness inside a car, all valid sub-assemblies have to be loaded, which then form a virtual harness assembly.

In general, harness CAD sub-assemblies are a static representation of the maximum space reservation for a particular installation space for a certain physical harness, including no further information about its inner structure. The models don't focus on the product structure of the harness but on the structuring of the installation space. Therefore, they represent an extent, which can't be built in reality, i.e. there is no corresponding hardware to a sub-assembly. Each model has its specific validity, mainly related to model series, variant and steering type. In order to reduce complexity, the number of sub-assemblies is kept as low as possible. Therefore, identical extents are represented within one model to avoid redundancies. As long as the routes of different hardware modules don't differ, there is no differentiation inside the CAD models (see Figure 3).

Because of this, a particular model always describes elements of one physical harness only. The routes which are shown inside the sub-assembly are the same for each valid variation, i.e. for each combination of model series, variant and steering type that the sub-assembly is valid for. Moreover, the sub-assembly represents a maximum extent, considering space reservation and the number of connector housings.



Sub-assembly represents **routes** of *Harness1* within the *middle* of *Installation Space 1*, that are equal for variants *A,B,C,D* in *Left Hand Drive*.

The diameter thereby shows the **maximum space reservation**.

Figure 3. CAD sub-assembly of an automotive wiring harness

Both the positioning of elements and the method of structuring the harness models, depend on the product structure level. Sub-assemblies of level 1 are defined in top-down design, representing a certain installation space and harness. Elements of level 2 (i.e. inside the sub-assembly of level 1) are built up using the bottom-up approach. The positioning of elements additionally depends on its type. The sub-assemblies themselves have no position inside the product, as most objects within are positioned relative to the global car coordinate system. As an example, the position of connector housings and fixings is defined with global coordinates as well as the so-called skeletons. These skeletons provide the interlinks between the different installation spaces and serve as an interconnection point for bundles. Therefore, they are defined within one sub-assembly in relation to the global coordinate system and afterwards interlinked to the adjacent sub-assemblies. This ensures that the harness as a product always consists of connected bundles. Bundles are created on routes, which always start and end in either a connector housing, a branch out or a skeleton. Wire protections, such as tubes and tapes, are defined relative to the bundle.

The information about the harness contents within a sub-assembly is needed for the topological aspects in wiring harness manufacturing. For this reason, this information is extracted from each model and afterwards merged with all valid model extractions for a specific harness. [Neckenich et al. 2015] describe in detail the follow-up process, in which topological information of CAD and logical information of schematics is merged and both a release drawing for product documentaiton and a manufacturing drawing is made out of, gathering all necessary information of a particular harness.

4. Extended assembly-oriented design for automotive wiring harness

Automotive wiring harness lacks a realistic CAD product that corresponds to the hardware product. Moreover, the two-dimensional master drawings, which are used for product documentation, represent "a disproportionate extent, which will never be built in reality" [Neckenich et al. 2015]. Because of this, there is the need for a 3D master model for wiring harness, based on an extended assembly-oriented design approach. Therefore, this section focuses on the model structure of the 3D master model and introduces the extended assembly-oriented design approach for automotive wiring harness.

4.1 Basis

A virtual harness is represented by several sub-assemblies. To reduce data waste and to ensure to get only the needed data, an adaptation of the current sub-assemblies is necessary. Structuring elements enable different views on the data inside a model. By default, each model contains two different views: entire part, which covers all the existing data, and final part, which only refers to the data needed for visualization inside the EDM viewer. In order to provide an encapsulation of the data, an additional topology view is added to the sub-assemblies and all relevant topology data is assigned to this view (see small boxes in Figure 4). This includes all parts and routes; it excludes the existing space reservations inside the model.

4.2 Model structure

In the first step, the master (top assembly) has to be defined. Detailed analysis has shown that it is best to create one top assembly for each steering type of a model series and to cover as many variants as possible. This definition has to be made with regards to the manufacturing situation - the master should cover all variants that can be manufactured on one formboard due to their similarity in topology. The result of this first step is an empty top assembly with a certain validity (regarding model series, variants, steering type and physical harness).

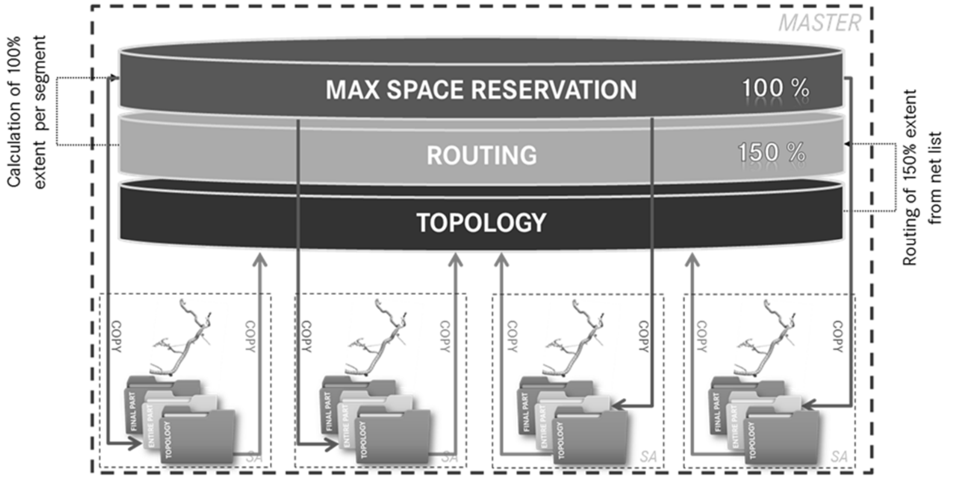


Figure 4. Extended assembly-oriented design for automotive wiring harness

All sub-assemblies (SA) that are affected by this validity are attached to the top assembly, which doesn't contain any further information at that moment (see Figure 4). All data related to the elements inside the sub-assemblies is hidden. By copying the encapsulated data from the topology view to the topology layer inside the top assembly, the master gets the topological information which has been defined inside the sub-assemblies. A persistent naming mechanism guarantees that the copied elements still keep a reference to their originate elements. By using the skeleton method as an interface between the different sub-assemblies, it is ensured that a closed network of routes is built in the top assembly.

A routing algorithm inside the master uses this topology and creates bundles on the routing layer, using the defined routes. Thus, it uses the imported net list information from schematics, which contains all valid wires for the chosen harness. The created bundles represent a disproportionate extent (equal to the content of the wiring harness master drawings), which will never be built in reality. As mentioned above, the focus of the harness assembly models is on representing the maximum space reservation. Thus, a configuration algorithm calculates the maximum realistic diameter for each segment and creates space reservations on the dedicated layer. At this step, the top assembly consists of three layers, the first containing the topological information, the second containing bundles and the third containing space reservations. Both the second and the third one referring to the topology in the first layer. In order to update the shown space reservation inside, the information about the maximum space reservation also has to be transferred back to the sub-assemblies.

4.3 Model relations

Models have various relations to different other objects. Therefore, we now focus on the distinct relations that can appear by using the extended assembly-oriented design for automotive wiring harness (see Figure 5).

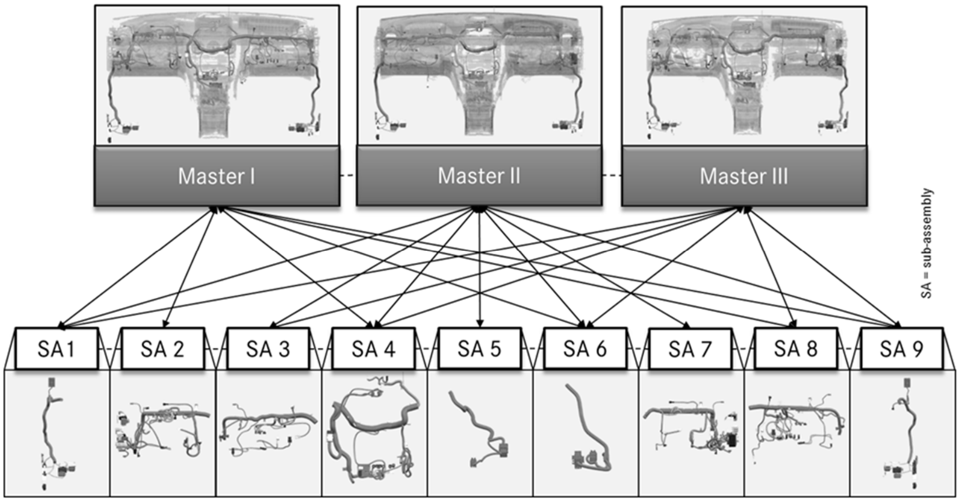


Figure 5. Model relations in the extended assembly-oriented design approach

4.3.1 Model-to-model relations

The sub-assemblies within a master can be related to each other in four different ways, comparing their related section of the physical harness as well as their connection to each other.

Two models might have no connection to each other and represent different sections of a physical harness, which is the simplest relation as no relation exists. Furthermore, two models can have one or more connections, being adjacent to each other. In this case the interface is represented by the skeleton which interlinks the routes in both sub-assemblies. Another possibility is found in two models connected to each other and showing the identical section of the physical harness. The two sub-assemblies simply represent alternative routes, but have identical segment lengths and same relative positions of parts. This relation is a direct result of the 3D master approach, which combines both the information of the whole physical harness and the representation of all installation spaces. For this reason, there is a parent model for each installation space (and consequently for each section of the physical harness) within one master and all models that show alternative routes in this installation space are children to this parent. A persistent naming mechanism ensures the correlation of all children objects to their parents. If the fourth case is matched, the sub-assemblies have been modeled incorrectly, as they represent the same section of the physical harness but don't have any connection to each other.

4.3.2 Model-to-master relations

Sub-assemblies are attached to a master when using the extended assembly-oriented design approach. Consequently, there are two possibilities of model-to-master relations. On the one hand, a model is only attached to one master. This happens if the complete validity of the sub-assembly is a subset of the master's validity. On the other hand, a sub-assembly can be attached to several masters. This occurs if only a part of the validity of the sub-assembly is a subset of the master's validity. In this case, an extended algorithm for the downstream process is needed.

4.3.3 Master-to-master relations

Sub-assemblies can be part of several masters. That is why the relation between different masters also has to be regarded. Each master represents a certain physical harness and transfers its content to its specific formboard. The masters themselves don't have a direct relation to each other, as there is no data transfer or model interaction between them.

4.4 Data transfer between master and sub-assemblies

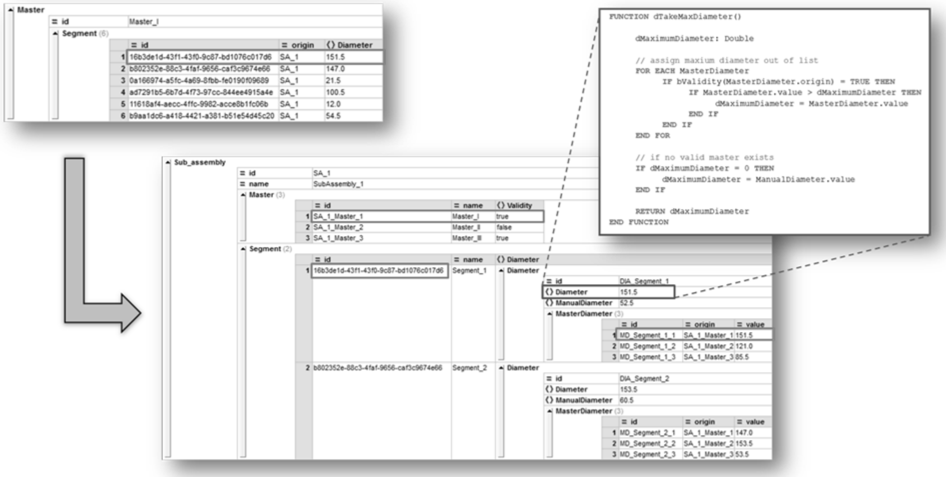
The master forms a top assembly collecting the valid sub-assemblies. The general structure and the relations between the different models have already been described. Now we focus on the data transferring processes between master and sub-assemblies.

4.4.1 Input data

By building an encapsulation inside the sub-assemblies, only the needed data is made visible to the top assembly. The assignment of all routing relevant data to the topology view enables the master exclusively to copy the needed information. Furthermore, the master recognizes existing parent-child-relationships between the sub-assemblies and just imports the topology information of parent models. This avoids the reading of redundant routing and path information from models that represent the same section of a physical harness.

4.4.2 Output data

Following the 3D master methodology, all needed data for follow-up processes can be found in the top assembly. As soon as the 150% extent has been routed and the 100% extent per segment has been defined and calculated, the new information has to be transferred to the downstream models, i.e. to all sub-assemblies belonging to the master.



Master

= id: Master_I

Segment (6)

	= id	= origin	{} Diameter
1	16b3de1d-43f1-43f0-9c87-bd1076c017d6	SA_1	151.5
2	b802352e-88c3-4faf-9656-caf3c9674e66	SA_1	147.0
3	0a166974-a5fc-4a69-8fbb-fe0190f09689	SA_1	21.5
4	ad7291b5-6b7d-4f73-97cc-844ee4915a4e	SA_1	100.5
5	11618af4-aecc-4ffc-9982-acce8b1fc06b	SA_1	12.0
6	b9aa1dc6-a418-4421-a381-b51e54d45c20	SA_1	54.5

Sub_assembly

= id: SA_1

= name: SubAssembly_1

Master (3)

	= id	= name	{} Validity
1	SA_1_Master_1	Master_I	true
2	SA_1_Master_2	Master_II	false
3	SA_1_Master_3	Master_III	true

Segment (2)

	= id	= name	{} Diameter
1	16b3de1d-43f1-43f0-9c87-bd1076c017d6	Segment_1	Diameter
2	b802352e-88c3-4faf-9656-caf3c9674e66	Segment_2	Diameter

Diameter (Segment_1)

= id: DIA_Segment_1

{} Diameter: 151.5

{} ManualDiameter: 52.5

MasterDiameter (3)

	= id	= origin	= value
1	MD_Segment_1_1	SA_1_Master_1	151.5
2	MD_Segment_1_2	SA_1_Master_2	121.0
3	MD_Segment_1_3	SA_1_Master_3	85.5

Diameter (Segment_2)

= id: DIA_Segment_2

{} Diameter: 153.5

{} ManualDiameter: 60.5

MasterDiameter (3)

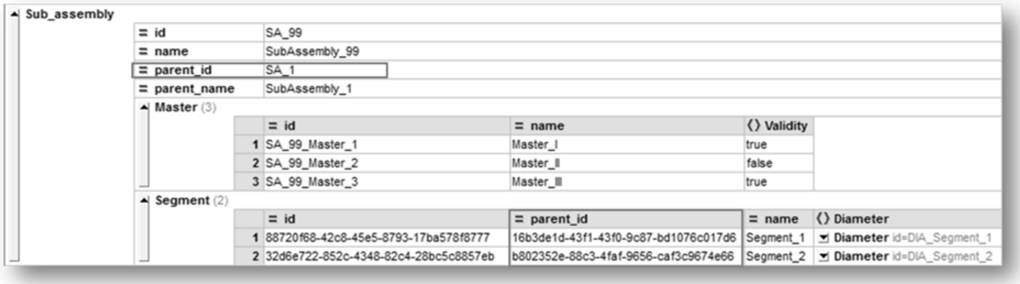
	= id	= origin	= value
1	MD_Segment_2_1	SA_1_Master_1	147.0
2	MD_Segment_2_2	SA_1_Master_2	153.5
3	MD_Segment_2_3	SA_1_Master_3	53.5

```
FUNCTION dTakeMaxDiameter()

    dMaximumDiameter: Double

    // assign maxium diameter out of list
    FOR EACH MasterDiameter
        IF bValidity(MasterDiameter.origin) = TRUE THEN
            IF MasterDiameter.value > dMaximumDiameter THEN
                dMaximumDiameter = MasterDiameter.value
            END IF
        END IF
    END FOR

    // if no valid master exists
    IF dMaximumDiameter = 0 THEN
        dMaximumDiameter = ManualDiameter.value
    END IF

    RETURN dMaximumDiameter
END FUNCTION
```

Figure 6. Downstream data transfer including an algorithm for diameter assignment

The first step to enrich the sub-assemblies with data from the master model is to change them from static to dynamic. By adding parameters to the system, i.e. by using parameterized space reservations, it is possible to integrate an algorithm that adapts and controls the diameter of the space reservations. Thus, it is important to know about the model-to-master relations. As described above, a model can belong to several masters, so several masters will calculate different segment diameters and write them to the sub-assemblies. As shown in Figure 6, the import data of the master carries the unique id of the segments and the calculated diameter. By using a persistent name mechanism, it is ensured that the data can be transferred to the corresponding object within the sub-assembly. The sub-assembly knows about its valid masters. Furthermore, each segment of the model consists of several diameters. On the one hand, it has the pre-defined manual diameter, which results from the early development phase, when only rough estimations have been possible. On the other hand, it has diameter attributes for each master the sub-assembly belongs to. The particular values for a certain master are overwritten when importing the master data. An algorithm checks for the maximum valid diameter that results from the master diameter attributes and assigns them to the parameterized space reservation. Thus, it is ensured that the sub-assembly always shows the maximum space reservation for its valid variants - as it has been defined for a sub-assembly in the beginning.

The second step regarding output data is to analyse the data transfer to child models. The overall process is the one described above. The only difference appears in the assignment of diameter values to the corresponding segments. Inside a child model, each object knows about its parent (see Figure 7). This means each segment has an attribute referring to the ID of the parent segment. Therefore, when importing the master diameter information the correlation is not matched on the unique ID, but on the parent ID. This again represents one kind of encapsulation.



Sub_assembly

= id	SA_99
= name	SubAssembly_99
= parent_id	SA_1
= parent_name	SubAssembly_1

Master (3)

	= id	= name	⟨⟩ Validity
1	SA_99_Master_1	Master_I	true
2	SA_99_Master_2	Master_II	false
3	SA_99_Master_3	Master_III	true

Segment (2)

	= id	= parent_id	= name	⟨⟩ Diameter
1	88720f68-42c8-45e5-8793-17ba578f8777	16b3de1d-43f1-43f0-9c87-bd1076c017d6	Segment_1	Diameter id=DIA_Segment_1
2	32d6e722-852c-4348-82c4-28bc5c8857eb	b802352e-88c3-4faf-9656-caf3c9674e66	Segment_2	Diameter id=DIA_Segment_2

Figure 7. Parent reference information inside a child-model

The master model doesn't need the detailed information of the child models, as this would be redundant data. For routing, only parent models are relevant. Nevertheless, the child models have to be kept updated in order to show the maximum calculated diameters. This is ensured by using the extended assembly-oriented design approach.

5. Validation

The presented extended assembly-oriented design approach for automotive wiring harness using 3D master models has been validated and tested in an industrial prototype application. Hence, real data and models of a cockpit car harness of a specific car line with several derivates have been used. For modelling, a total number of 38 sub-assemblies have been used, being integrated in four different masters. These masters vary in steering type and derivate and are built up according to the different existing formboards for this cockpit harness. Seven diverging parent-child-relationships are implemented by the sub-assemblies. The single sub-assemblies differ in the number of attachments to master models: five are attached to only one master, 28 belong to two masters and five sub-assemblies are integrated in four masters. The validation has focused on the model structure, the import of encapsulated data and the routing for the whole extent of sub-assemblies. The downstream data process has been confirmed by a proof of concept with two sub-assemblies. The knowledge gained from model structuring has been implemented in current CAD development processes and has also been documented as design rules for future CAD development processes of wiring harnesses at an OEM. Being able to handle the existing model variety of harness assemblies, combining installation space-oriented design and hardware orientation as well as distinct data flows, interfaces and encapsulation have been verified as main benefits of the concept. The results of these validations have shown that the presented approach is a solution for what is lacking in today's automotive wiring harness CAD development.

6. Conclusion and outlook

Assembly-oriented design, as well as using parent-child-relationships and parametric models, is state of the art in today's industry. Modelling automotive wiring harnesses differs from other industrial applications as it focuses on installation spaces rather than on the final product. We have described the use of CAD models in automotive wiring harness development and have shown that the introduced extended assembly-oriented design approach enables the combination of installation space-oriented design on the one hand and hardware orientation on the other hand. The requirements and preconditions of the concept, such as encapsulation of data inside as well as the validity of the sub-assemblies, have been presented. We have provided a brief outline of the different steps of data creation inside the master model, in which the logical information of the netlist is merged with the copied topology of the sub-assemblies and the maximum space reservations per segment is calculated and stored in different layers. The model relations between masters and sub-assemblies have been analysed. Data transfer processes within the presented design approach for automotive wiring harnesses, as well as resulting algorithms that are essential for the correct data assigment, have been introduced and explained. The validation of the concept has shown that it is a solution for what is lacking in today's automotive wiring harness CAD development. Since this is based on common methods of assembly-oriented design, the developed approach can also be transferred to other use cases outside of the automotive wiring harness.

This paper has presented a basic step for using 3D master method in automotive wiring harness development. Future work will focus on an optimization of the existing algorithm for calculation of maximum space reservation inside the master model and especially on the engineering change management process and its influence on the 3D master approach for wiring harness development.

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