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# Process-based Assembly Technical Annotation Management in 3D Assembly Instruction

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**Abstract.** In order to instruct on-site workers to accomplish the assembly job fast and exactly, improve the assembly quality and efficiency, we proposed a management method for assembly technical annotation in 3D assembly instruction. This method maps 3D technical annotations to assembly operation and assembly time based on time sequence granularity, achieves the goal of showing assembly technical annotations based on assembly process. We demonstrated the effectiveness of this method with a satellite antenna feed component's assembly process instance. The instance shows that this method can mark assembly technical annotations based on assembly process, and show the annotations in time sequence but not in assembly space. This will help on-site assembly workers to understand the assembly order fast and unambiguously, finish the assembly operations correctly.

## Introduction

Assembly is the process to combine and connect large number parts according to the design drawings and technical requirements, and install all of the parts to the correct position [1]. Assembly instruction is the carrier of assembly process information, and the main basis for assembly worker to execute assembly operation [2]. The adoption of MBD technology provides accurate data source for assembly instruction through adding assembly operation information at assembly process planning phase for product 3D model [3, 4]. 3D model can be embedded in assembly instruction to express assembly process efficiently because of accurate content expression, intuitive appearance and dynamic simulation capability [5, 6, 7].

But there is still one problem to be solved that the on-site workers can't real-time view the assembly technical annotations according to the assembly sequence when the assembly process is simulated, because the assembly technical annotations are marked in specific model view for each assembly operation which are static and independent of assembly time. Assembly is the process based on time sequence; consequently, the assembly technical annotations should be viewed according to the assembly sequence instead of assembly space which is suitable for product designer to view design annotations based on product structure and shapes.

So, when 3D assembly instruction needs to be published, one key issue is how to improve the process oriented marking and displaying capability of assembly technical annotation. We proposed a method which can mark and display assembly technical annotations based on time sequence granularity.

## Assembly technical annotation association based on time sequence granularity

MBD technology supports multiple kinds of technical annotations which are overall called Product and Manufacturing Information (PMI). Annotations are used to provide complete product definition to comply with ISO 16792:2006 [10].

The assembly process oriented PMI, i.e., assembly technical annotation, is quite different from the ordinary design PMI which are space-based annotations [9, 10], because they are timing-based annotations. The assembly technical annotation such as assembly datum, gummed area, size of initial hole and so on, is directed at specific assembly environment and assembly process, and is meaningful only when the actual assembly occurs. Assembly technical annotation reflects the relation for assembly process in two major ways: assembly procedure and assembly time.

When the same part or assembly unit participates in multiple assembly operations or steps with different kinds of assembly jobs and assembly positions, it need be marked with multiple technical annotations. For example, in the assembly operation, an assembly torque should be marked on a part to ensure appropriate preload; and in the next inspection operation, an inspection requirement for assembly clearance should be marked on the same part. Meanwhile, an assembly technical annotation may be shown in multiple assembly operations or steps. For example, if a turbo-shaft participates in multiple assembly operations, but the surface lubrication requirement is the same, the surface lubrication annotation should be shown in multiple operations. So, the assembly technical annotation is closely related to assembly procedure.

Furthermore, because of the different instruction function and importance, different assembly technical annotations should be displayed in different time length. For example, the screw direction annotation just needs to display at beginning of the nut assembly step to prompt on-site worker, but the torque must display across the entire step to ensure preventing the force of worker is too large or too small. So, the assembly technical annotation is also closely related to assembly time.

Obviously, the way of model view can't meet the management requirements of timing-based assembly technical annotation. So, we extend the assembly process model to three layers: entity layer, annotation layer and application layer in order to associate the assembly technical annotation with assembly procedure and assembly time as shown in Fig.1.

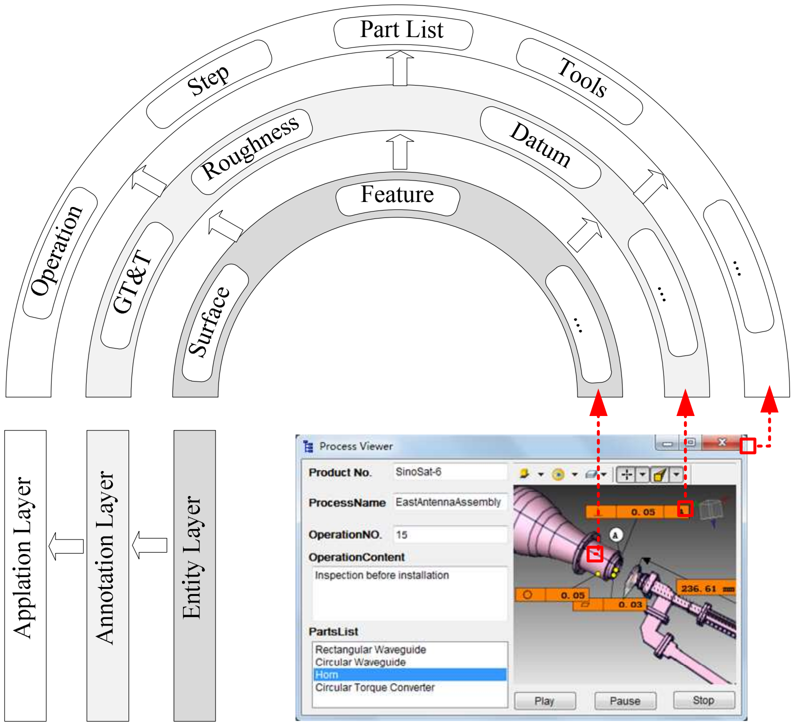


Figure 1. Organization framework of assembly MBD model

Entity layer is composed of geometric information of 3D model. Entity information is the core design data of 3D model and the carrier of assembly technical annotations. Its change is not allowed in the manufacturing process, but annotation information can be added on it. Annotation layer defines the GD&T, roughness, process requirement, datum and other technical annotation information. In general, the information of annotation layer is directly displayed on the 3D model, and directly managed as part of 3D model. The data of annotation layer is main content of assembly process MBD model. Application layer supports the assembly-oriented application based on assembly technical annotation. Application layer data are structured such as parts list, tools. In general, application layer data are the management information of assembly instruction, not directly shown on the 3D model.

So, the assembly technical annotation can be associated with assembly process through associating annotation layer with application layer.

A time sequence granularity method is proposed to associate assembly technical annotation with assembly procedure and assembly time, manage their relationship, and display annotation according to the corresponding granularity. The assembly procedure and assembly time can be divided into different granularities.

Assembly procedure granularity is divided into assembly order, assembly operation and assembly step granularity based on the level of assembly process. Any technical annotation can be associated with the assembly order, any assembly operation and any assembly step. If the annotation is associated with assembly order or operation, this annotation will be displayed across entire assembly order or operation. If the annotation is associated with assembly step, which is only to say this annotation will appear in this step, but the length of display time is uncertain. The time length of annotation display in assembly step is determined by the assembly time granularity.

Assembly time granularity is divided into full time, time span and timestamp granularity. Full time granularity means the technical annotation will be shown across entire assembly step. Time span granularity means the technical annotation will be displayed for a period of time in the step. Timestamp granularity means the technical annotation will only show at a specific time point in the step. The assembly simulation can be paused for several seconds in order to help workers to observe the annotation conveniently.

The key frames of assembly simulation process can be used to control the assembly time granularity. The time period of full time granularity begins at the original key frame and ends at the final key frame of the step. The time period of time span granularity begins at the specific key frame and ends at the next specific key frame of the step. Timestamp granularity only needs to be associated with a specific key frame.

The logical technical framework of time sequence granularity method is shown as Fig.2.

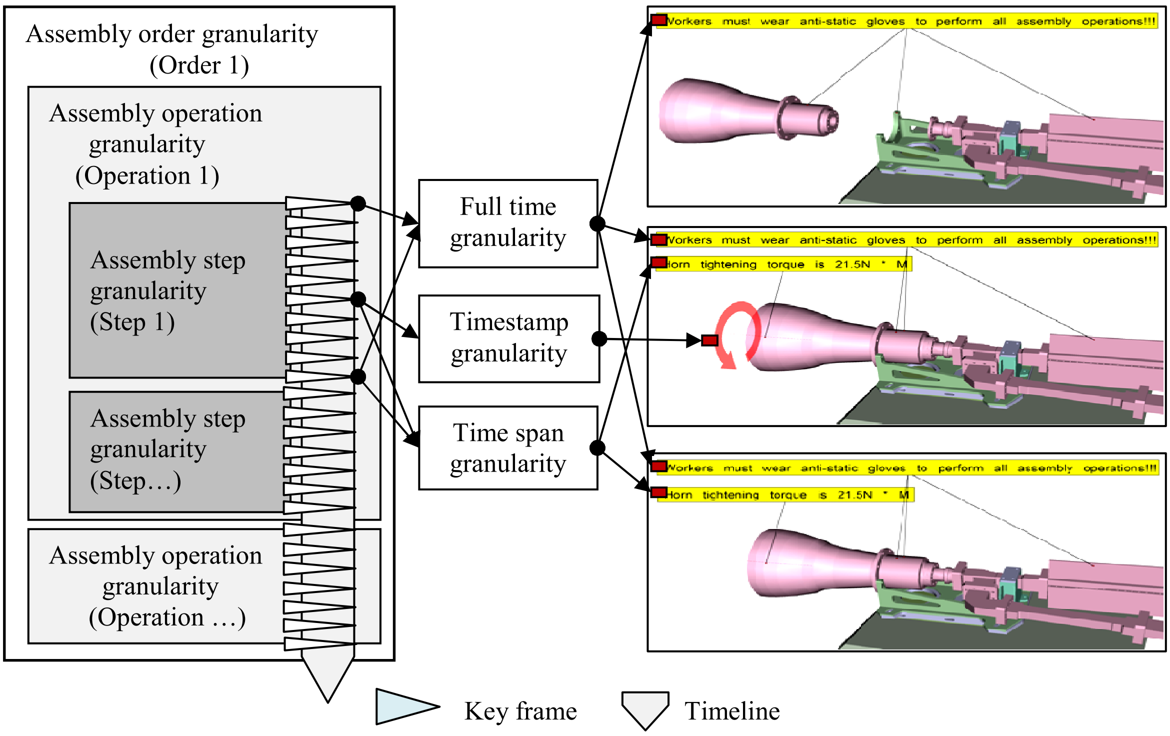


Figure 2. Time sequence granularity method logical technical framework

### Assembly Technical annotation dynamic control based on mapping

Annotation entity is one kind of entities in 3D model to implement the PMI annotation. Each annotation entity has a unique ID. So, the mapping information of annotation entity ID and time sequence granularity can be built and be used to dynamically control the annotation to show or hide.

In this paper, mapping unit is defined as *ATSMapping* (Annotation and Time Sequence Mapping). The mapping information is described with standard XML format, and the XML schema is expressed as Fig.3.

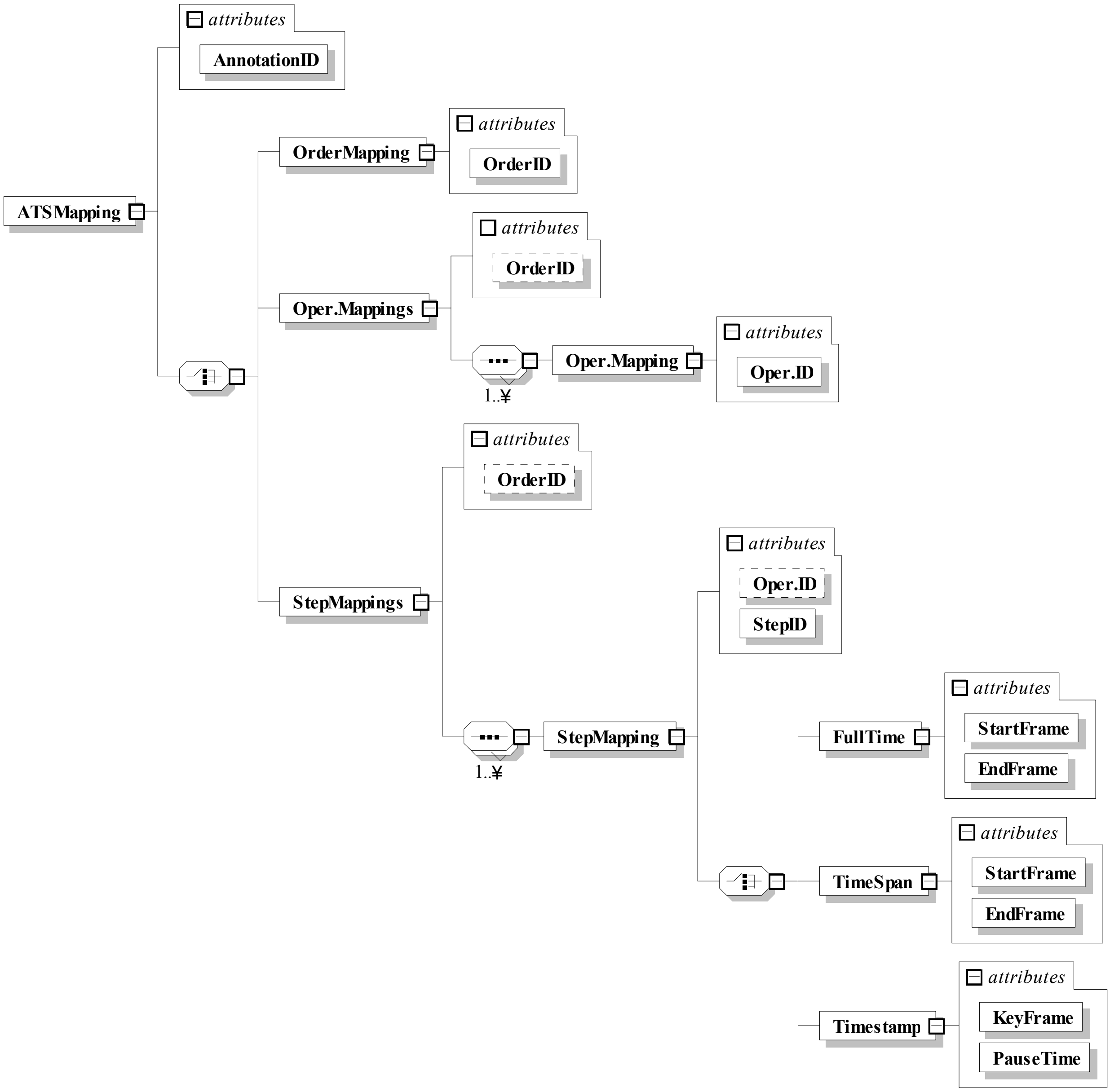


Figure 3. XML schema of the mapping relation of annotation and time sequence granularity

For example, the ATSMapping of timestamp granularity annotation in Fig.2 can be instanced as the followings.

```
<ATSMapping AnnotationID="Annotation 3" >
    <StepMappings OrderID="Order 1">
        <StepMapping Oper.ID="Operation 1" StepID="Step 1">
            <Timestamp KeyFrame="6" PauseTime="4"/>
        </StepMapping>
    </StepMappings>
</ATSMapping>
```

When the mapping relation has been built, we can use this information to dynamically control the annotation to show or hide and the annotation show time with the followings control rules:

**Rule 1:** For the annotation with order granularity, it will be shown across the entire assembly process.

**Rule 2:** For the annotation with operation granularity, it will be shown when the simulation goes to this operation, and hidden when this operation ends.

**Rule 3:** For the annotation with step granularity, that is divided three cases:

1) If full time granularity, the annotation will be shown across the entire step, when the step ends, the annotation is hidden.
2) If time span granularity, the annotation will be shown at the start key frame, and hidden at the end key frame.
3) If timestamp granularity, when the simulation goes to the key frame, the annotation will be shown, and the simulation will be paused for the specified time, then the simulation continues and the annotation is hidden.

## Instance and Conclusion

We selected the east antenna of a commercial communication satellite as the application object to verify this method. The assembly process of east antenna contains 26 major assembly operations. Some assembly operations must deal with the assembly of complex components. For example, Ku feed component of east antenna contains 121 major parts， its assembly operation contains 25 assembly steps.

The technical validation process is shown as follows:

1) Use the Adobe Lifecycle Designer to design the PDF template of antenna assembly process card.
2) Use DELMIA to plan the assembly process of the antenna, and form the assembly operations and assembly steps.
3) Edit assembly animation and markup the technical annotations in 3D Via Composer, build the mapping relation of annotations and the assembly procedure and time with customization function using 3D Via Composer Player (as shown in Fig. 4).
4) Release the assembly model to PDF file with U3D lightweight model format, Generate the PMI display control script based on the mapping information, and embed the scripts into PDF file.
5) Finally, generate the singly integrated 3D assembly instruction file; interact with assembly process through command buttons, and display PMI based on time sequence granularity (as shown in Fig.5).

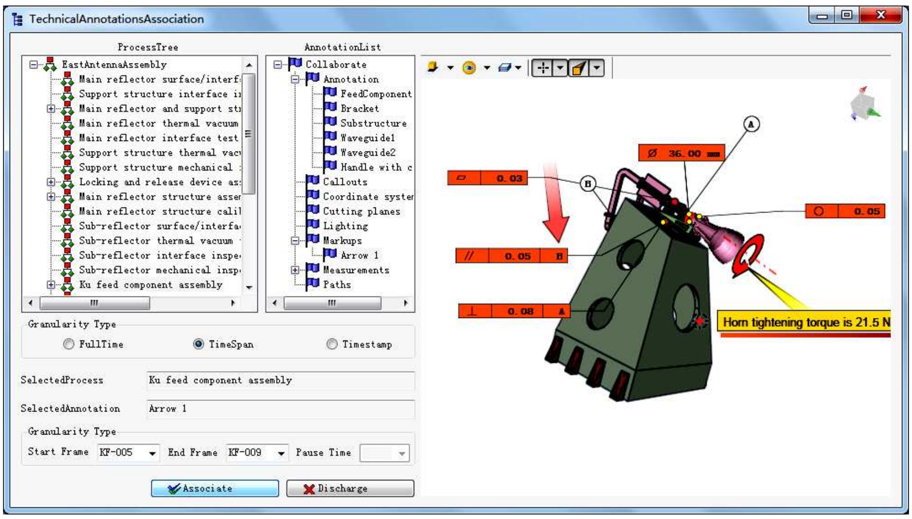


Figure 4. Associate technical annotations with assembly process in Composer Player

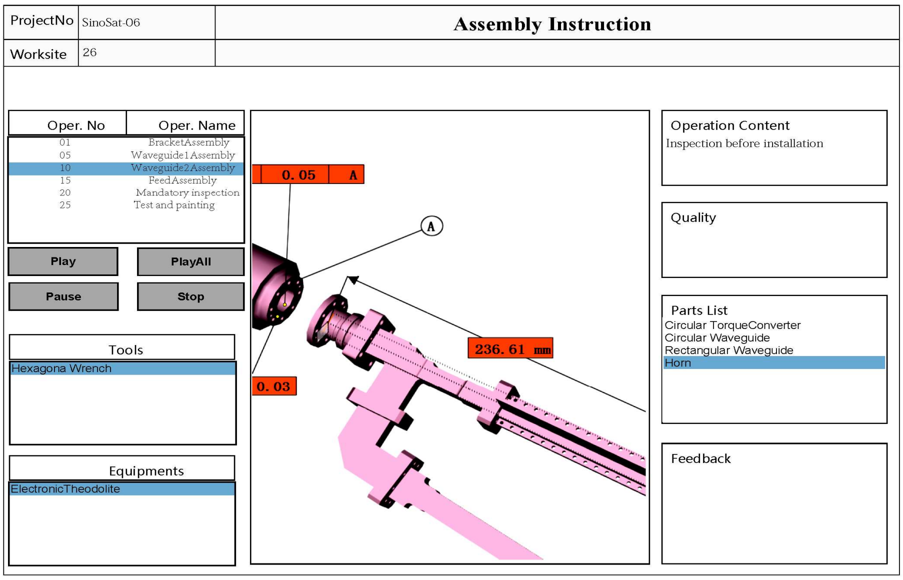


Figure 5. Show assembly technical annotations based on assembly process in 3D assembly instruction

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