Interoperability of Assembly Analysis Applications through the use of the Open Assembly Design Environment

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Abstract

The emergence of high performance computing has opened up new avenues for the design and analysis community. Integrated Product/Process Design techniques are allowing multi-functional teams to simultaneously optimize the design of a product. These techniques can be inhibited, however, due to software integration and data exchange issues. The work outlined in this paper focuses on these issues as they relate to the design and analysis of electro-mechanical assemblies. The first effort of this work is the creation of an open environment, called the Open Assembly Design Environment. The goal of this environment is to integrate the otherwise disparate assembly design tools using a central control system and a common set of data. These design tools include virtual reality based design systems, CAD systems, DFA systems and process planning systems. This paper will outline the overall goals of the project, present the architecture designed for the system, describe the interfaces developed to integrate the systems, and discuss the data representation requirements for a system integrating a virtual reality system with CAD systems.

Keywords: Open Systems, Assembly Design, Virtual Assembly, Integrated Product/Process Design, STEP

Introduction

With the emergence of high performance computing, new avenues for improvement are opening up to the design engineering community. Computationally intensive analysis models that previously were considered unwieldy and too complex to solve are being re-examined as candidates for solving.

Along with advances in high performance computing have also come advances in high performance communications. This improvement in communications has lessened the impact of physical distances on design tasks and has resulted in reconsideration of design projects where design tasks are geographically dispersed. With this rapid evolution of advanced computing and communication it is pertinent that design applications maintain pace so that the greatest positive impact on product design process can be achieved.

The concept of Integrated Product/Process Design (IPPD) is an engineering approach that integrates activities from product concept through production and field support, using a multi functional team to simultaneously optimize the product and its manufacturing process to meet cost and performance objectives. This approach is directed to achieve a more optimal design, which ultimately determines the product's success or failure, by the consideration of many factors throughout the life cycle of the product.

One part of this life cycle are the factors relating to the assembly issues of the product. Assembly engineering activities are generally considered after component form, materials and tolerancing have been completed. These components are then passed on to manufacturing and assembly engineers who are tasked with determining the best method to assemble the components. The manufacturing and assembly engineers usually have little knowledge of the component design rationale and are reliant on the engineering specifications and drawings to determine the optimal process to manufacture or combine the components into a functional assembly.

The timing of these manufacturing and assembly engineering activities usually prevents any major redefinition of the upstream specifications without significant impact on product schedule and costs. This less-than-optimal product realization process has resulted in increased industry efforts to investigate new avenues for incorporating conventional downstream activities earlier in the design cycle at an appropriate level of detail, thus providing a more robust design.

In recent years, concurrent engineering has received considerable focus in attempting to reduce the life-cycle costs associated with a product realization process. It has been demonstrated and stated in many forms that a significant portion of the costs associated with a product is established during the early phase of design. Most companies have reacted to this by eliciting input and support from different groups, representing areas that have an effect on life-cycle costs, earlier in the design cycle. In particular, Design for Assembly has received considerable acceptance in providing a structured approach to reduce the assembly cost and time while improving the quality of the final product.

A prototype system called the Open Assembly Design Environment, or OpenADE, is currently being developed at NIST. This system is being designed to provide a fully integrated assembly design environment linking otherwise disjointed tools in a fashion that will allow engineers to analyze assembly designs from the concept stage through final process plan development. OpenADE includes an open architecture that provides standard interfaces for linkages to assembly analysis applications; integration and interface mechanisms supporting augmented CAD systems; and the support for interoperability between applications through the exchange and sharing of data using standard data representations.

The emergence of augmented CAD systems requires advances in engineering and manufacturing methods, data representations, and data flow. One such augmented CAD system is that for virtual assembly. Virtual reality systems can be viewed as a natural extension or enhancement to current CAE systems, yet very different methods are used to visualize and manipulate the underlying product model. This results in a separation of data between the VR systems and that of the CAD systems. Through the OpenADE project, NIST is analyzing these needs for the standardization of assembly data representations. A prototype system is being developed linking modern computer-aided design tools with emerging virtual prototyping and analysis tools using one comprehensive representation of assembly data. This paper discusses the OpenADE architecture, a virtual assembly tool developed as part of the OpenADE project, the data requirements for such a system, and a prototype system based on the OpenADE architecture.

Related Work

A common focus found in several research groups is the need to create a single environment that can be used to integrate disjointed computer-aided engineering systems such that they perform as one larger contiguous environment. These individual systems have not only been analysis systems, but also database and communications systems, providing centralized data storage and long distance communications capabilities.

Integrated Product Design Environment

A joint project between Boeing, Arizona State University and MacNeal-Schwendler Corporation is aimed at developing an Integrated Product Data Environment or IPDE [Lian97, Qure97]. The goal of the work is to allow individual CAD/CAE tools work together by interfacing with a central database called the Integrated Product Database. The IPDE will store data such as geometry, analysis information, feature information, manufacturing data, etc.

Each CAD/CAE tool would communicate with a Data Access Interface (DAI). The DAIs are responsible for transforming the CAD/CAE tool-specific data into a form required by the IPDE. Each DAI communicates with a Shared Data Manager (SDM) that accesses the database. The SDM includes management tools for communications, version control, query access, and component relationships.

The system will utilize the STEP standard as a means of communication and for storing the product data. Specifically, AP203 and AP209 are being used for the prototype implementation of the system. This work is currently being supported by DARPA, and the general concept and architecture has formed the basis for the OpenADE project.

Intelligent Assembly Modeling and Simulation

Carnegie Mellon University has developed an environment for the simulation and visualization of assembly design and planning [Gupt97]. The goal of this work was to develop a system composed of simulation agents that would provide the user the ability to analyze assemblies in a detailed enough manner to eliminate the time and cost consuming practice of physical prototypes. The current environment consists of five components; an assembly editor, a plan editor, a workspace editor, a simulation controller and an animation viewer.

The assembly editor is used to import data from CAD files of individual components from ACIS-based solid modeling systems and organize it into an assembly representation. The editor recognizes joints between parts through the use of feature recognition techniques. The plan editor utilizes user provided sequence and tooling information to generate tool and part motions. This information is then synthesized with the assembly workplace environment using the workplace editor. The simulation controller and animation viewer provide the user the capability to setup and view the assembly process that has been created with the earlier tools interactively. These simulations can include interference analyses and stability analyses. The users have the capability to access any assembly operation in the sequence as well as change their viewpoint of the operation.

Virtual Prototyping Framework

Isothermal Systems Research (ISR) and Washington State University have developed an open architecture framework for the integration of virtual prototyping tools commonly used for mechanical components [Jaya96]. This object-oriented framework utilizes a plug and socket analogy. This technique would allow any virtual prototyping system to plug into the overall system if the correct constructs were followed.

An implementation of the framework was created to integrate the software systems being used at ISR for the Automated Design, Analysis and Manufacturing (ADAM) system. The ADAM system automates the entire design cycle of spray cooling equipment. The C++ implementation included a parametric CAD system, a finite-element modeling system and a database system for storing the life-cycle information.

Computer Support for Current Design Using STEP

The Fraunhofer-Institut fur Graphische Datenverarbeitung has created a system called CoConut: Computer Support for Concurrent Design Using STEP [Jasn94]. This system provides an open environment for the integration of existing applications and data with new techniques into a single CAD environment. The integration of these applications and techniques is based on an object-oriented model and the use of international standards such as STEP.

CoConut is broken down into two main areas. The first area consists of the communications system, the database management system, and the user interface system. The second area consists of the CoConut cockpit, the person/organization tracking system, and the project/product tracking system

The communications system is responsible for the message distribution and broadcasting services. The database management system provides access to the data in the distributed database. This data can be specific to an application or generic data stored in a neutral format. The user interface system provides generic methods for providing a common interface across the various applications of the CoConut system.

The CoConut Cockpit is the main user interface of the system, providing such services as help, application initiation, environment setup, and message tracking. The person/organization and project/product tracking systems provide the functionality to create, modify, and visualize information that is related to the product, the project, and the people involved in the project. Authorized users can set up the data structures and project leaders can authorize project teams to have access to this data.

Overview of the Open Assembly Design Environment

The primary focus of OpenADE project is to develop an operational prototype of the system that can be accessed by a distributed community of users. To demonstrate the feasibility of approach to the creation of an improved comprehensive assembly design system, the OpenADE provides extensions to the current assembly functionality of CAD systems and provides mechanisms to integrate other assembly-related software technologies.

An initial architecture for OpenADE has been defined, based on the Integrated Product Data Environment (IPDE) work of Boeing, Arizona State University and MacNeal-Schwendler Corporation [Lian97, Qure97], supported by the Defense Advanced Research Project Agency Rapid Design Exploration and Optimization Program. The OpenADE system utilizes the general concepts of this work but has been developed independently and concentrates specifically on assembly analysis. This architecture, adapted to the OpenADE project, can be seen in Figure 1. This shows the key components: the STEP schema based integrated design database, the suite of data and system managers, the assembly application access interfaces, as well as any required CAE tool. A better understanding of the tasks involved in realizing this architecture can be achieved through the description of each component and how each component relates to the others.

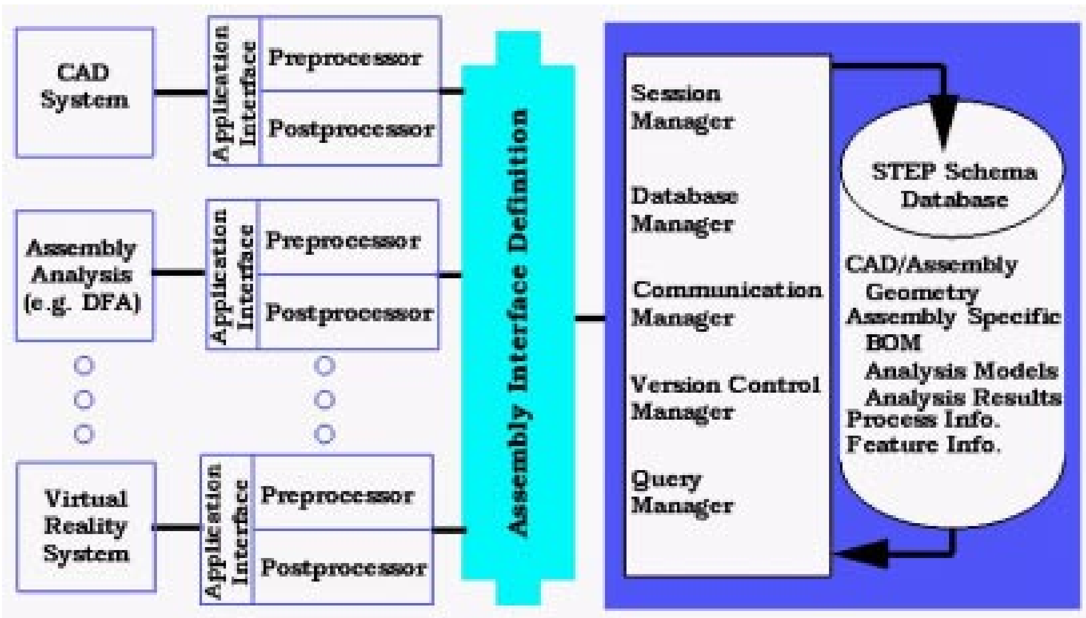

Figure 1. Architecture of OpenADE

At the heart of the OpenADE system is the integrated design database. This database stores all information that is required by any component of the OpenADE system, as well as any information that is generated by the components. All data will be stored via the STEP schema, using Part 21 for all text encoding. Currently, proprietary data formats are being used. Examples of data include CAD and assembly geometry, assembly configurations, bill of materials information, analysis models, tesselated models, analysis results, process information, and feature information.

With all of the data being stored in a centralized location, there will be a large requirement for managing this data. This will be the responsibility of the design database manager. This manager is responsible for providing the mechanisms to query data, define relationships between data, maintain meta-files, maintain version control, and performing other pertinent services. All data communications within the OpenADE system will be performed through the design database manager. When a specific program requires a piece of information from the database, the database manager will query the database for the information. If the information is not available, the manager will then query an application that can provide that information. This information would then be written back to the database and would then be available to be passed back to the initial requesting application.

Interoperability

One of the key issues addressed by the OpenADE system is the need for interoperability between the various applications and components of the system. It is a natural connection to look into the on-going efforts of ISO TC184/SC4 in the standardization of data models facilitating the exchange of product design information. For assembly analysis and data representation, the most relevant engineering standard is the emerging international standard ISO 10303 or STEP (STandard for the Exchange of Product data). Various parts of STEP, such as AP203 provide the means for the transfer of product models, but are limited to only representing assemblies as a collection of 3D objects positioned and oriented in space. There is no provision to capture the logical relationships between parts, the mating feature relationships, part functionality, kinematic information or tolerance information. The OpenADE project is researching these needs of assembly analysis applications, including emerging technology applications such as virtual assembly, to determine the set of data requirements needed for interoperability.

The set of data representations that is being developed through the OpenADE project, will be transmitted between the database and the various applications that compose the OpenADE system through the Assembly Application Access Interfacess (AAAI). Each AAAI will be developed for a specific application that meets the specifications of an assembly interface definition. For example, an assembly interface definition will be developed for computer-aided design systems. This definition will specify that a compatible CAD system must be able to provide certain data, independent of form and methods, to the OpenADE system. If a CAD system can provide this information, an AAAI can be written to link the database manager protocols to the those needed by the CAD application to access the information and process it into a form needed by OpenADE. Likewise, the reverse scenario would be true. The AAAI will specify what data can be provided from the database to the applications. The AAAI will be written to process this data into the form required by the specific application and provide the mechanisms for communicating with the application.

Data Requirements of a Virtual Assembly Tool

The first step in determining the data exchange and storage requirements for the OpenADE system was to analyze an existing assembly analysis system. Through a research contract with NIST, Washington State University has been developing the Virtual Assembly Design Environment, or VADE, system for investigating the use of virtual reality for assembly analysis. Several iterations of this software have been completed [Conn95, Conn96a, Conn96b, Conn97, Chan97]. This system is serving as one of the key components for analyzing the data requirements for assembly analysis when using a virtual prototyping tool and for testing the interoperability goals of the OpenADE system.

Current VADE Capabilities

The initial development of the Virtual Assembly Design Environment produced a system that is linked directly with Pro/Engineer and is dependent on the assembly being within Pro/Engineer to output the necessary data. The Virtual Assembly Design Environment allows a user to perform the following:

- Select an assembly in Pro/Engineer
- Specify a surrounding environment where the assembly will be performed
- Locate all components of the assembly in the environment at specific locations

- Export all of the above data to an immersive virtual environment
- Enter the virtual environment to perform/evaluate the assembly process

Within the virtual environment (see Figure 2), the user can do the following:

- View the entire environment in a stereoscopic, immersive environment
- Select a part or subassembly to be assembled to a "base" part
- Use an instrumented glove (Cyberglove) to manipulate a graphical representation of the user's hand
- Reach and grab the part/subassembly in a realistic manner (unrealistic grasping does not allow the user to grab the part)
- Manipulate the part/subassembly into it's final location with respect to the base assembly
- Perform the above operation for all the parts/subassemblies in the environment

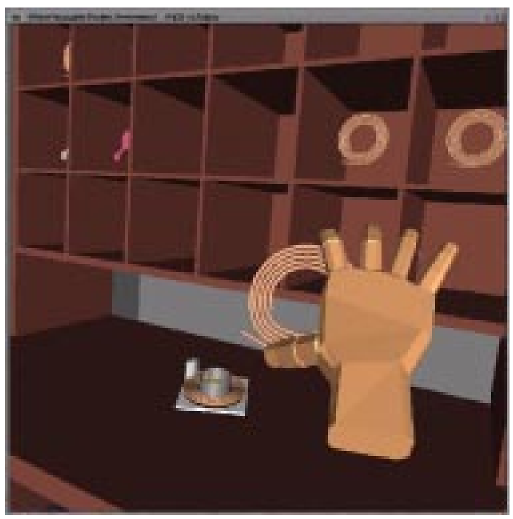

Figure 2. User's Perspective within VADE using an HMD

During the part manipulation/assembly process, there are several features that allow the system to simulate physical reality and allow the user to create valuable assembly information. One of the major problems in using an immersive virtual environment to create detailed engineering data stems from the lack of accuracy due to tracking errors and absence of physical constraints and supports. VADE compensates for this by simulating physical constraints during the assembly process when two parts are close to each other. The virtual constraints used for this simulation are the assembly constraints which are created in Pro/Engineer to assemble the parts. Thus, the designer's intent during the creation of the assembly model is automatically used while evaluating the design for assembly. During the assembly process, the user can "float" a partially assembled part and pick up another part to continue with the assembly. When all the constraints for a part are satisfied, the part is automatically "dropped" from the hand into the final assembled location.

The user can also create swept volumes while a part is being assembled. This is done by recording the trajectory of the part as it is manipulated into its final assembled location. The various instances of the recorded part motion are then presented to the user for acceptance/rejection/modification. The final accepted trajectory is then used to create a polygonal swept volume which represents the space used by the part during assembly.

Parametric part geometry modifications are also supported by VADE. This limited capability allows the assembly engineer to suggest design modifications to facilitate assembly. The part designer has control over the parameters which can be modified at the assembly evaluation level. Selected design parameters are earmarked in Pro/Engineer by the designer. These parameters are then made available in VADE to the assembly engineer. The VADE user can make changes to these parameters (which will typically change the geometry of the part). The modified parameters are sent back to Pro/Engineer where the part is updated using the parametric methods of Pro/Engineer. The geometry of the modified part is sent back and updated in VADE.

Data Requirements for VADE

Currently VADE is tightly coupled with the CAD/CAM system Pro/Engineer. The primary reason for this is that Pro/Engineer is able to provide VADE with most of the data required for proper operation. This tight coupling is being replaced by a more flexible and indirect coupling through OpenADE. Currently, the data required by VADE are the following:

1. Assembly Tree Data
   The most important information required by VADE is the hierarchy of components of the assembly. This information is supplied to VADE in terms of the following:
   - Name of the assembly
   - Number of children components (for only one level of the tree)
   - Names of the children
   - Transformation matrix specifying the final assembled location and orientation of each child component with respect to the parent assembly

2. Assembly Constraint Data
   The constraints created in the CAD system for assembling the component are used by VADE to simulate physical constraints, to support constrained kinematic motions and for recognizing when a component is fully constrained. At this time, only coordinate system mating, axis constraints, and planar constraints are supported. The constraint information is supplied to VADE in terms of the following:
   - Constraint type (coordinate system, axis mate, axis align, plane mate, plane align)
   - Offset data (offset between the feature on the component and the feature on the base component)
   - Coordinate system location and orientation for coordinate system constraints (in the component's local coordinate system)
   - Two end points for axis constraints (in the component's local coordinate system)
   - Three unit vectors and one point for plane constraints (two vectors on the plane, one normal to the plane and the origin of the plane, all in the component's local coordinate system).

   It is possible to overconstrain a component in Pro/Engineer. VADE has the intelligence to throw out redundant constraints based on the constraints which have already been applied to a component.

3. Component Geometry
   This information is required for the graphical representation of the components. This display data is a triangulated model of the component. Currently, only the Inventor format is

supported. Each component (part or subassembly) is required to have a separate file containing this data.

4. Environment Data
   This data is used to display the surrounding information and to initially locate the various components in the assembly environment. The surrounding environment data is provided to VADE in the form of an Inventor file. The global locations of the components are provided as triplets (x,y,z locations) for each component.

Data Created by VADE

When an assembly operation is performed, there are several pieces of information generated by VADE which could be valuable for transfer to other software systems or back to the original CAD/CAM system.

1. Swept Volume
   - For each part, the user has the option of creating a swept volume. This information is available as:
     - Trajectory of the component in terms of transformation matrices for each instance in the trajectory (with respect to the base component's coordinate system)
     - Triangulated swept volume which encompasses all the instances in the trajectory
     - Graphical representation of both of the above

2. Sequence of Assembly

3. Suggested Parametric Design Changes for the Component

4. Ease of Assembly

5. Reach and Access Problems

Analysis of Assembly Data Representations Requirements

As can be seen from the description of the data requirements and data generation capabilities of VADE, there is a wealth of data required and available during assembly analysis. A portion of this data can be obtained or transmitted using current data standards, however much of the data cannot be stored using current representations. Of these data representations that are available. however, there is often no link or association between the various components of the data. The VADE system has been built to account for this lack of association and internally maintains the links between data components.

The first set of data that is needed is the assembly tree. This is currently stored in a WSU proprietary data format. This data could be obtained from the current release of STEP AP203: Configuration-Controlled Design through the Bill of Materials Unit of Functionality (UoF). This provides the hierarchy of the assembly and the transformations of each part for placement within the assembly. This, however, is a very small subset of the overall data that is contained in AP203 and the overhead involved in transferring all of this data is large.

The second set of data required is the assembly constraint data. This data is also contained within the WSU proprietary data format file. This information is not available for exchange in any current STEP standards. However, work is ongoing in the area of constraints for STEP to represent constraints between geometric entities within a model as well as constraints between components [Prat96]. Through funding from NIST for the OpenADE project, Wichita State University has been developing a constraint-based representation specifically for assemblies [Lyon97]. This representation would allow for the transfer of constraint data between assembly analysis systems.

The third set of data required by VADE is the component geometry for the graphical representation of the parts. This graphical representation requires a faceted or triangulated model. A faceted boundary representation UoF exists in AP203 under conformance class 5. If an application supports this conformance class then AP203 could successfully transfer this data. However, neither Pro/Engineer or I-DEAS MasterSeries currently support this class. Therefore, an alternative means of transferring this data was used, Inventor files. This file format is an industry standard that helped form the now international standard, the Virtual Reality Modeling Language, or VRML.

The last set of data required by VADE, the environment data, actually requires a combination of the earlier data representations with additional information. The environment data is an assembly itself. Thus, the environment requires the same hierarchical information, transformation information, and graphical representation information. Additionally, the environment data requires the added information regarding the initial placement within the environment of the components of the assembly being analyzed. This type of data is unique to virtual assembly systems and therefore does not exist in any available standard.

The first set of generated data by VADE is that of the swept volume. This involves the generation of a trajectory and a triangulated or faceted representation of the volume. The trajectory can be described using elements available in STEP Part 42: Geometric and Topological Representations and the faceted representation UoF. The association of a trajectory and the corresponding swept volume with an associated part within a specific assembly is not supported by any current standard.

The sequence of assembly in an important aspect in the development of the process plan of an assembly. Within STEP, there is Part 49: Process Structure and Properties, which is used in AP213: Numerical Control Process Plans for Machined Parts. This AP, however, is out of the scope of assembly analysis and a lot of unnecessary overhead would be incurred to utilize this AP for sequence representation.

The ability for an assembly analysis system to communicate with a CAD system to transfer design changes based on the user's analysis of the current design is not a data representation issue for storage. However, it is a data representation issue in terms of the interoperability of analysis systems. If a user is required to repeat model design changes in two different analysis systems, then undue overhead is occurring. This results in duplication of effort in the design process involves lost time. To link systems together would involve providing the means for the two systems to have message passing capability.

The last two pieces of information that can be gained through the use of a virtual assembly system such as VADE are the ergonomic results of ease of assembly and reach studies. This data is difficult to quantify, although it is important information to capture. This type of data is currently not available in standard representations.

Additional Assembly Data Requirements

There are additional data requirements pertinent to assembly analysis that are not currently supported by VADE. Thus, to provide full interoperability among assembly analysis systems there are additional data requirements.

1. Tolerance Data
   An important set of data for assembly design is that of tolerancing. The tolerance data exists at both the part level and the assembly level. As the tolerancing of parts and assemblies is being developed during the design process in one tool, the effects of such data should be able to be analyzed in other tools. Dimensional tolerance information is currently not supported under STEP AP203, but is under AP214: Core Data for Automotive Mechanical Design Processes, which is a larger effort than just assembly analysis. Under the OpenADE project, a large amount of work is being done on both tolerance analysis and synthesis to drive the standards efforts for dimensional and assembly level tolerancing [Nara98, Suda97].

2. Material Properties
   The material properties of the components in the assembly are an important design factor. These material properties can be used by systems that incorporate physical-based modeling in the analysis, such as friction and gravity. A material properties UoF for STEP is not included under AP203.

3. Process Plan Information
   More detailed information regarding the process plan is an important aspect of assembly design. Other than sequence of assembly, information regarding timing, fixtures, tooling, etc., needs to be captured and stored, especially in the later stages of design. As mentioned earlier, Part 49 of STEP does contain process information. However, the Process Specification Language project at NIST is investigating and developing a specific language for storing process information [Schl96]. This project is aimed at driving future standards in this area.

Prototype System

The prototype OpenADE system is being developed to demonstrate the generation, transfer and storage of the assembly data described above between several assembly analysis systems. The prototype system will include two CAD/CAM systems, Pro/Engineer and I-DEAS MasterSeries; an immersive custom built virtual assembly tool, VADE; and a commercial virtual prototyping tool, dV/Mockup. Figure 3 shows a more detailed look at the implementation of the OpenADE system.

The conceptual view of the architecture shown in Figure 1 can be seen imbedded in Figure 3. The overall system is being developed as a client-server system using an object-oriented design approach with C++. The server side of the system contains the session manager, the database manager, and the database itself. Additionally the database manager contains a query manager for handling all queries to the database. The session manager is responsible for managing all clients of the OpenADE system. Each client for the OpenADE system is called a session client. A session client represents a design session that has been started using the OpenADE system. This session will exist with the assembly through the design life cycle. OpenADE provides the facility for multiple simultaneous active sessions, all under the control of the session manager. This design session contains information regarding the user, the assemblies being analyzed, the applications being used with the associated application interfaces, as well as a dedicated user interface. The user interface is currently being developed using the Fast Light Toolkit Graphics Library, available under the GNU License.

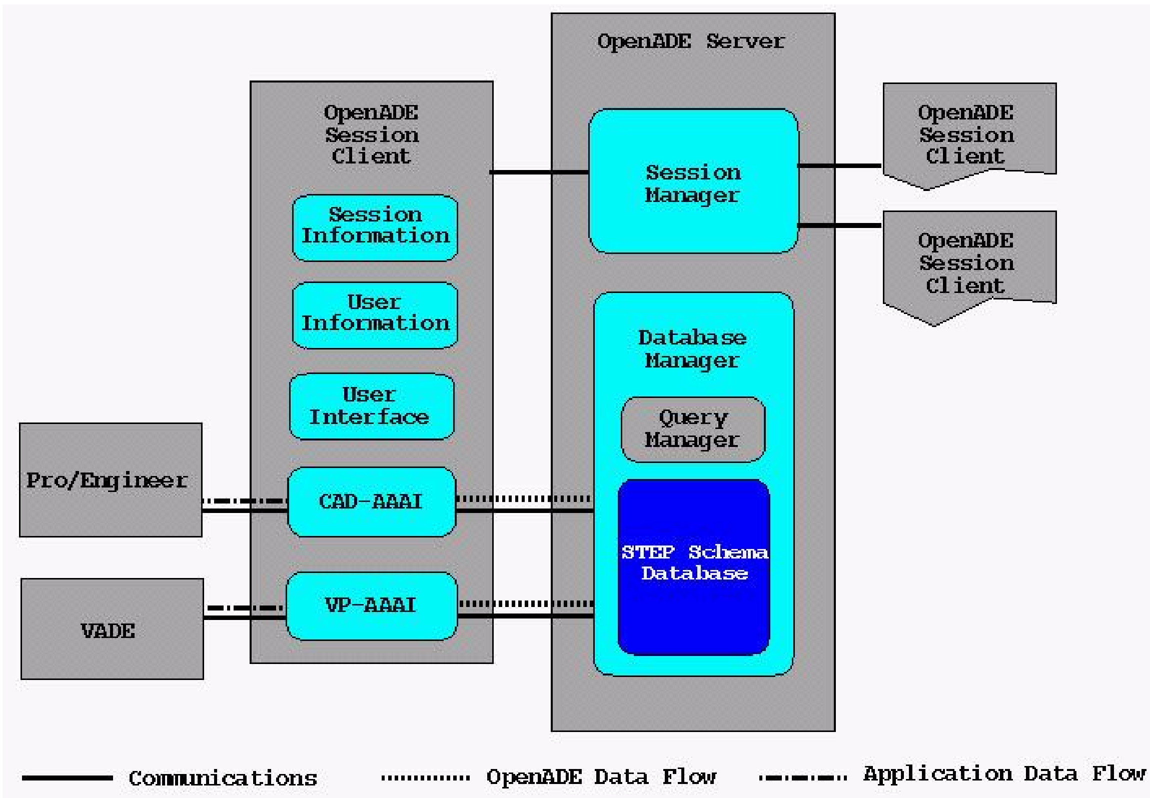

Figure 3. Implementation of OpenADE

When the user first starts the OpenADE system, the server system is started and then a client session login facility is provided. Once the user logs into the system, a session client is started and is linked to the server. The user is provided with the main console of the system presenting them with several options and a list of any other person currently using the system. The user has the ability to start a design session, query other users on the system to determine if the models the user wants to analyze have already been checked out, send a talk request to another user or logout of the system. A snapshot of this screen can be seen in Figure 4. If the user elects to start a session, a new session window, shown in Figure 5, is displayed. The session window provides the user with a list of the existing design sessions that have been initiated, the ability to select and resume a session, create and start a new session or query a session. Querying the session provides the user with information regarding the session such as who initiated the design session, a description of the session, what is the assembly model involved, when was it initiated and when was it last worked on. Starting a new session involves selecting an available assembly model or starting a new model and providing a description for the design session. A sample image of the window is shown in Figure 6. Once the user has elected to resume an existing design session or start a new one, the user is then presented with the application window. This is a list of all applications that are currently available to the user to analyze the assembly. This can be seen in Figure 7, showing the applications being used in the prototype system. Finally, once the application has been selected, the server determines the appropriate application interface that needs to be used and provides that information to the session client. The session client then adds the AAAI to the session and uses it to start and link to the desired application and to retrieve the necessary data from the database, by way of the database manager. As stated earlier in the paper, the AAAI converts the OpenADE data into the application's required data format. And, as data is saved, the AAAI will translate the application data into that required by OpenADE. Figure 8 shows a user using VADE through the OpenADE system at NIST.

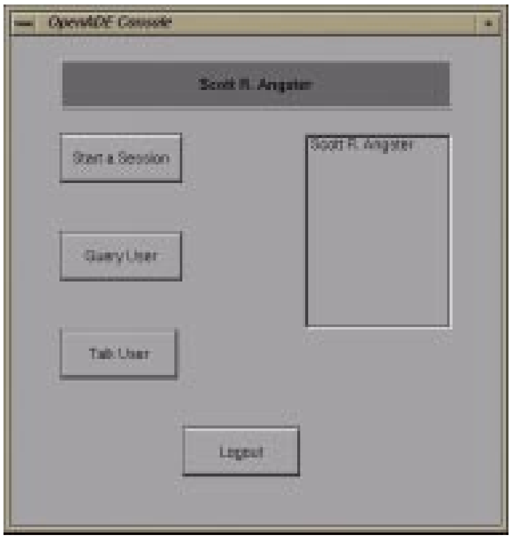

Figure 4. OpenADE Console

Figure 5. Session Window

Figure 6. New Session Window

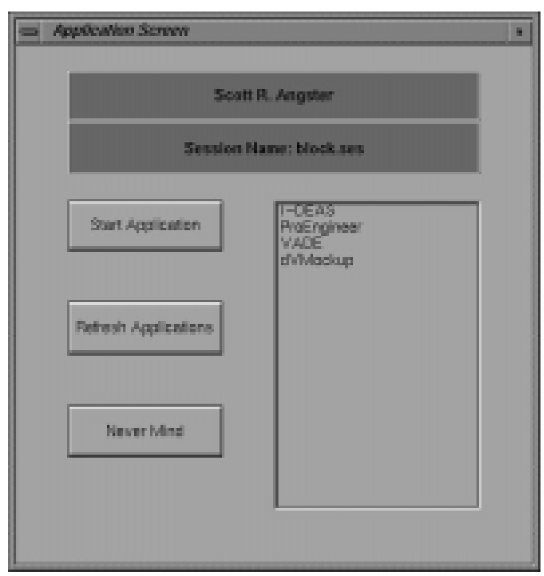

Figure 7. Application Window

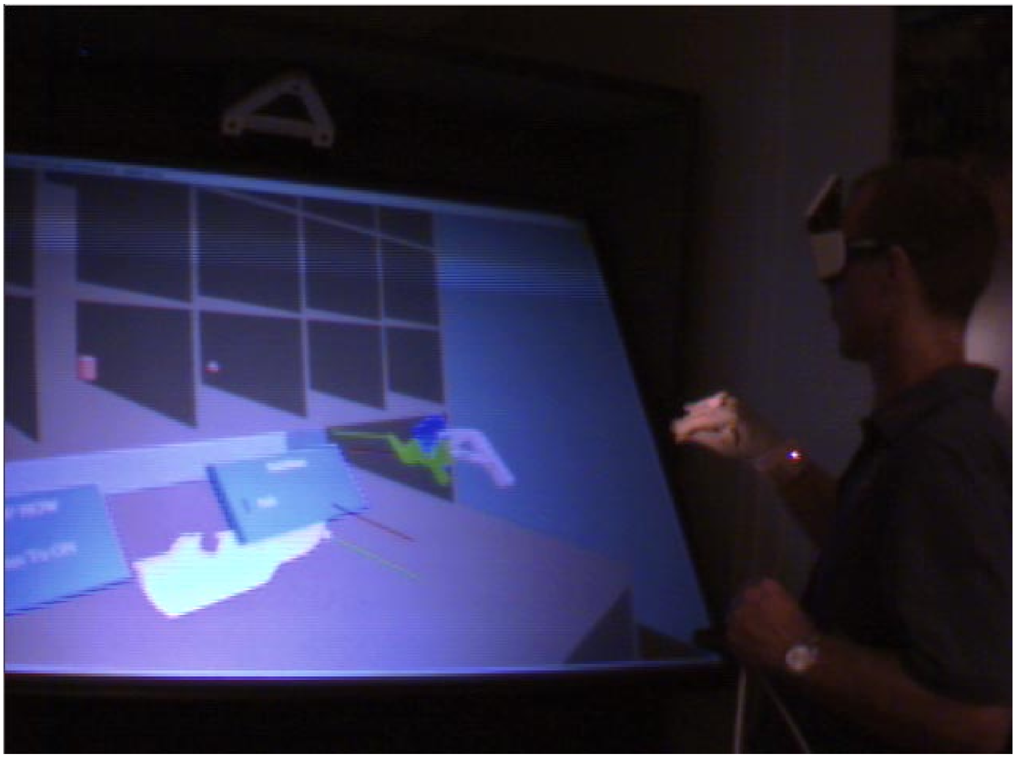

Figure 8. VADE Application in OpenADE Installed at NIST using the ImmersaDesk™

Broader Scope of OpenADE

This paper has focused on the identification of data requirements for the interoperability of assembly analysis applications and the development of a architecture to support this interoperability. The OpenADE project, however, has a larger focus. There is a large amount of work supported by OpenADE in the development of new techniques and methodologies for improving the assembly design process. This includes the work on assembly-level tolerancing, constraint based representations, process planning, knowledge-based assembly design and virtual assembly techniques. A more detailed look at the overall OpenADE project can be found in [Lyon98].

Conclusions

This paper has presented an overview of the goals of the Open Assembly Design Environment project and a prototype implementation. The main goal of this project is the development of the necessary data representations to support an open system for the design and analysis of electro-mechanical assemblies, as presented here. These representations must be able to support technologies and techniques such as virtual assembly, assembly-level tolerancing, constraint-based specification, sequence analysis and stability analysis. Additionally, these data representations must not only support each one of these technologies and techniques, but also support the interoperability of the tools built around them. A brief overview of the available standards for these data representations was given. It can be seen in this overview that much of the needed data representations could be supported within the STEP environment, either in the present release or future releases. However, there is no one application protocol that can support all of the needs of assembly analysis, such as data relationships. This may require the development of a new application protocol for this field. The OpenADE project goal is to further investigate these needs.

7. Disclaimer

Certain commercial equipment, instruments, or materials are identified in this paper. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products identified are necessarily the best available for the purpose.

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