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DISTRIBUTED COLLABORATION: ENGINEERING PRACTICE REQUIREMENTS

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Abstract. *Designing a structure follows a pattern of creating a structural design concept, executing a finite element analysis and developing a design model. A project was undertaken to create computer support for executing these tasks within a network supported collaborative environment. This study focuses on developing a software architecture that integrates the various structural design aspects into a seamless functional collaboratory that satisfies engineering practice requirements.*

The collaboratory is to support both homogeneous collaboration i.e. between users operating on the same model and heterogeneous collaboration i.e. between users operating on different model types. Collaboration can take place synchronously or asynchronously, and the information exchange is done either at the granularity of objects or at the granularity of models.

The objective is to determine from practicing engineers which configurations they regard as best and what features are essential for working in a collaborative environment. Based on the suggestions of these engineers a specification of a collaboration configuration that satisfies engineering practice requirements will be developed.

1. INTRODUCTION:

1.1 SUBJECT

The development of a software architecture, that integrates structural design aspects into a seamless functional collaboratory that satisfies engineering practice requirements.

1.2 BACKGROUND

The design of civil engineering structures follows a particular pattern:

1. Creating and developing a structural concept that is portrayed in structural drawings.
2. Based upon the conceptual drawings a finite element analysis (FEA) is executed.
3. From the results of the FEA and the geometry of the structure, a design model is developed.

To facilitate the various design tasks a project was undertaken to develop a software tool that would allow the execution of these tasks to take place within a collaborative environment. Due to the magnitude of the project it was subdivided into various studies that dealt with the following basic requirements:

1. Finite element analysis
2. Structural steel member design
3. Structural steel connection design
4. Integration of these models within a collaborative environment.

During studies 1-3 attempts were made to harmonize the respective application architectures, to assist in the development of a collaborative environment and integrating these studies into that environment. The focus of this study is to develop a software architecture that integrates the structural design aspects/models mentioned into a seamless, functional collaboratory that satisfies engineering practice requirements.

1.3 OBJECTIVES

- Establish a collaborative working environment for the design of steel structures.
- Synchronize and integrate software architectures of various design models within the collaborative environment.
- List collaboration architectures.
- Discuss advantages of operating within such an environment to practicing engineers.
- Evaluate feedback from the engineers.
- Specify a collaborative environment that satisfies engineering requirements.

2. INTEGRATION OF SOFTWARE ARCHITECTURES.

In the process of structural design the structural concept is designed in the form of drawings. Based on these a FEA is executed to determine the forces and displacements in the structural model. Lastly a design model is developed from the FEM and the geometry of the structure, which in this case comprises the connection design and the member design model.

2.1 THE FINITE ELEMENT MODEL

The FEM model is developed to determine the forces and displacements that could exist within a structure. In a FEM model the following needs to be defined:

1. The nodes and elements that compose the structure.
2. The material and cross-section properties.
3. The supports and constraints which represent the boundary conditions existing within a structure.
4. The forces acting upon a structure such as own weight and applied external loads.

Figure 2.1 shows an example of such a finite element model.

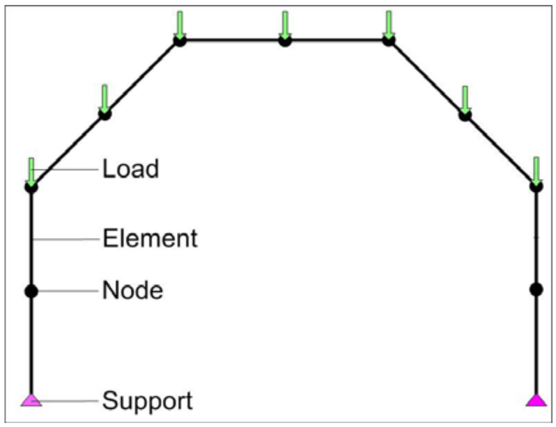


Figure 2.1 Example of a Finite Element Model

2.2 THE MEMBER DESIGN MODEL (MDM)

The MDM is responsible for designing the structural members of the structure. To design the members it is necessary to know their geometry of the structure and what forces they are subjected to. The FEM model contains this information; therefore the MDM is based upon the FEM.

As shown in Figure 2.2 the design members can comprise of several finite elements and does not need to start or end at finite element nodes. This means that the design of members is not restricted by the definition of the finite elements. Furthermore the restraints and boundary conditions applicable to a design member must be defined by the user, since it cannot be derived from the FEM model. This has been done so that the member design is not limited by the FEM model yet still uses the FEM model to obtain the geometry and internal forces.

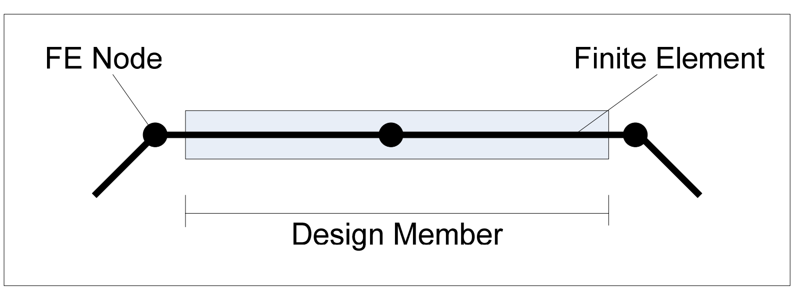
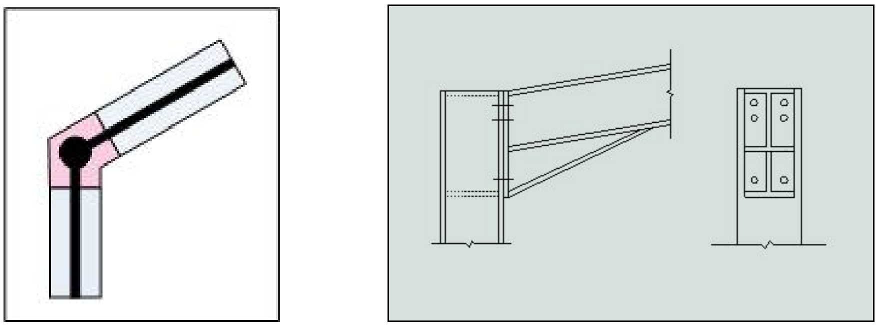


Figure 2.2 Member design based upon FEM

2.3 THE CONNECTION DESIGN MODEL (CDM)

The CDM is used to design the connections that hold the individual members of the structure together. In order to design a connection one needs to know which members are to be connected and the forces that exist within a connection. This information is contained in the FEM (forces) and the MDM (members), therefore the CDM is based upon these two models.



(i) (ii)

Figure 2.3 (i) A connection to be designed from MDM and (ii) an example of what such a connection looks like.

2.4 ACCOMMODATING CHANGES MADE TO THE FINITE ELEMENT MODEL

Since the MDM and CDM are dependent upon the FEM, changes made in the FEM have a direct impact on these models. The impacts of these changes vary in significance, from requiring little to no changes to be made in the other models, to having to completely recreate those models.

For example, changing some forces in a FEM will have no affect. Alternatively some geometrical changes may lead to having to entirely recreate the MDM. The accommodation of changes in the FEM in the MDM and the CDM is currently being researched.

2.5 INTEGRATION OF THE SOFTWARE ARCHITECTURES

The software architectures of FEM model, MDM and the CDM were developed independently of each other, with a focus to ensure that the individual models yielded accurate results in their respective designs. In the development process attempts were made to harmonize these architectures. However As time progressed and the software developed, understanding of basic architectural aspects grew, and so did some of the models. This caused inconsistencies to develop between the architectures as some of the earlier studies could not be kept up to date with the latest changes, due to time constraints. The first task was therefore to synchronize these architectures.

Furthermore the three models were developed to operate independently of each other, yet there are relationships that exist between these models. Figure 2.4 shows the relationships between the respective design models.

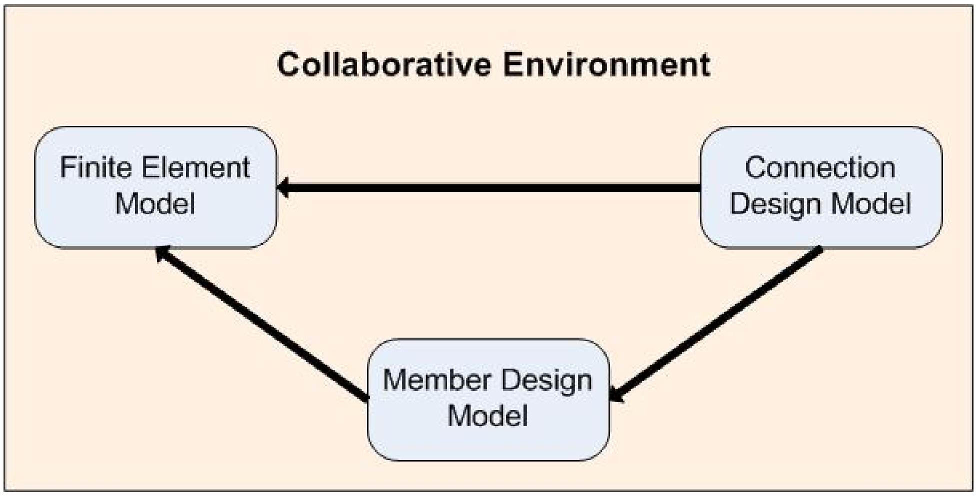


Figure 2.4 Relationships between the design models.

These relationships between the models were not implemented, and users had to define the inputs needed in the design models, e.g. the finite elements and forces needed to create the MDM were predefined. The collaborative environment was developed to establish the links between the design models.

3. THE COLLABORATIVE ENVIRONMENT

The overall purpose of the collaborative environment is to create an "easy to use" working environment for a group of engineers to assist them in the design process. Members of the group may be separated in time and space.

The collaborative environment is created through a client/server architecture and its main functions are:

1. To establish links between the various design models.
2. To connect users over remote distances.
3. To inform users about current project developments and updates.
4. To store and manage model files that are created and edited in the design process.

3.1 THE SERVER

The server is the heart of the collaborative environment. It satisfies the user/client information needs through making information accessible to different users over remote distances, whether the information is required from other users or from a centrally located file system. In figure 3.1 it can be seen how the server links everything together.

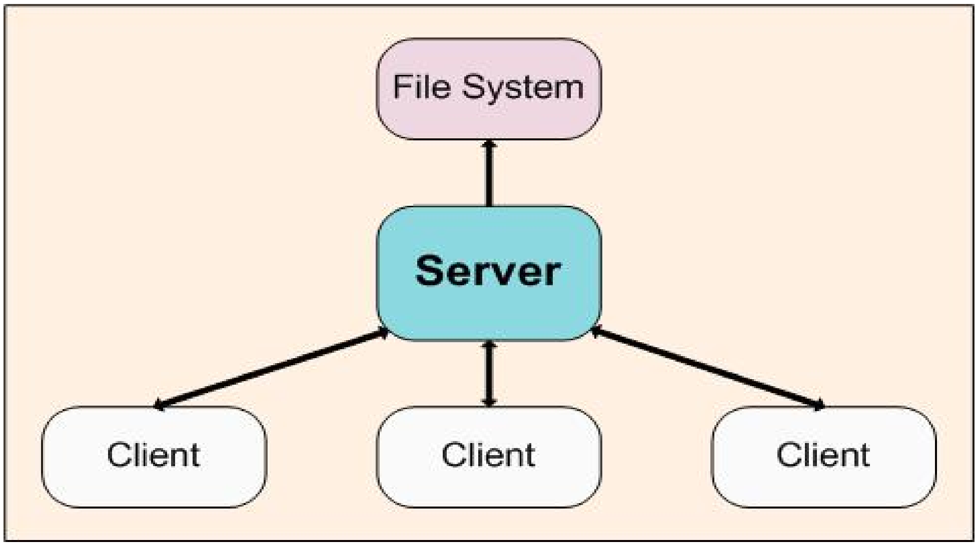


Figure 3.1 Layout of the overall system architecture

3.1.1 THE SERVER AS MANAGER

The server is the only direct link to the centrally located file system and acts as the manager of that file system. It is responsible for loading and saving files as requests from clients are made. In the process the server would ensure that certain criteria are met before executing certain tasks.

Criteria that the server would consider are security and accessibility. For security the server would check whether or not a client is allowed to access a specific file, and what type of access is allowed; may the client read, edit or delete that file.

Accessibility has to do with checking whether or not a file is currently accessible by a user. For instance if one user is busy with an existing file, another may not be allowed to access that same file at the same time. This is to limit the possibility of data corruption, should two users want to update an existing file at the same time.

3.1.2 THE SERVER AS MEDIATOR

The server acts as a mediator between the clients, and informs users of changes that have occurred in the design models. For instance, if one user updates a FEM model a message can be send to another user that is working on a MDM (which is based on that FEM model) that changes have occurred. Another possibility is to request approvals from other users for certain updates. This mediator service is to ensure that a consistent design is developed throughout the design process.

3.2 THE CLIENT

The client is the handle through which a user connects to the server to access the file system and communicate with other users. This communication between the server and clients is crucial for organizing the design environment, and establishing an effective collaborative environment.

The actual project designs and work takes place at the clients. Clients are mainly interested in the three design models; the FEM model, the MDM and the CDM.

3.3 INFORMATION EXCHANGE

In a collaborative environment two types of information exchange are of importance: (1) between users working on the same design aspects e.g. member design and, (2) between users that work on different design aspects i.e. finite element analysis and member design.

For synchronous collaboration in the first case users must be able to exchange information at the object level. Solutions to this problem are discussed in [Van Rooyen] and were not dealt with in this study.

In the second case, information exchange at the granularity of objects is not applicable. For this case exchange of versioned models is required. It was considered advisable to “freeze” models for these exchanges to avoid accidental corruption of information. Frozen models are not editable and can be accessed independently to make all the information contained in that model available to the user. The freezing of these models are still under investigation.

4. ENGINEERING PRACTICE REQUIREMENTS

The collaborative environment discussed in chapter 3 is only one of many possible collaboration configurations. It was developed as an example to engineers; to show what can be done and use it as a reference point. The objective is to use this environment to determine from practicing engineers what they liked and disliked about the environment, and what they would like to see in a collaborative environment. The main aspects to consider are:

1. The management architecture of the collaborative environment
2. Collaboration configurations for interaction between users
3. Additional features that would be useful

A Client/Server architecture with a centrally located file system was suggested to manage the collaborative environment. A possible alternative is a peer to peer architecture with a distributed file system. Some of the practical considerations that will influence the choice of management architecture are: security, file accessibility, file organization, available hardware, etc.

Collaboration between users can either be homogeneous (between users operating on the same model) or heterogeneous (between users working on different models, where dependencies between the models exist).

Consider the following scenario for homogeneous collaboration; several users are busy operating on a design model. One of the users makes changes to the model, consequently the models of the other users needs to be updated. These update can be synchronous (real-time) or asynchronous collaboration. When updates are done synchronously the option exists to do them automatically or request that users approve the changes before there models are updated. Asynchronous collaboration takes place when a user stores an updated model. Other users are now informed that the model has been changed and requested to allow their models to be updated.

Heterogeneous collaboration does not allow for synchronous updates to take place. A MDM can only be developed from an analyzed FEM model. FEM models sometimes contain errors which mean that they cannot be analyzed. Therefore no forces in elements can be determined and any design of members or connections is meaningless. Therefore heterogeneous collaboration is restricted to supporting asynchronous updates.

Research is currently in progress to determine the preferences of practicing engineers and what they regard as essential to operate within a collaborative environment. The objective is to establish a best practice policy for implementing a collaborative environment; which includes aspects like the architecture of the management system and the collaboration configurations. Of further interest is to determine what features are to be built into the environment to make it most effective in aiding the engineer.

5. CONCLUDING REMARKS

5.1 CURRENT STATUS

To date the architectures of the FEM model and the MDM have been synchronized. The collaborative environment, as discussed in chapter 3, has been implemented with collaboration between the FEM model and the MDM established.

5.2 CURRENT AND FUTURE INVESTIGATIONS

The extent to which a MDM can accommodate changes made in a FEM model is being investigated. Changes that need consideration are the following:

- New forces added to the model, or existing forces altered.
- Change of boundary conditions by adding, removing or editing supports.
- Elements that are added, removed or edited in the model.

In the immediate future interviews with practicing engineers are being arranged to obtain their input for the development of the collaborative environment. It is planned to sketch various scenarios of what is possible to the engineers, and then hear what they believe is best and what will work.

REFERENCES

[1] G. C. Van Rooyen, Structural Analysis in a Distributed Collaboratory, Dissertation, University of Stellenbosch, Department of Civil Engineering, 2002