DATABASDESIGN FÖR INGENJÖRER – 1DL124

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Assignment 4 - A Scientific Database for Discretized Mesh-Based Data

1.1 Goals

The exercise consists of the development of a small *scientific database application* for storing and retrieving information about data for plane (2D) discretizations (called a mesh or grid) of geometry domains. This mesh-based data can for example be used to represent and present spatial data, such as temperature fields over a geometric object. The student should implement schema definitions, populate the database and specify queries in AMOSQL, the query language of AMOS II. The goal of this exercise is to give a practical experience to develop a small database application using an object-relational database management system including an object-relational query language. We will work with the AMOS II object-relational DBMS which is a a research prototype system being developed at Uppsala Database Laboratory, Uppsala University. The AMOSQL query language is similar to the object-oriented extensions of the latest SQL:1999 standard. Several of the large commercial relational database vendors have started to introduce such object-oriented extensions in their SQL implementations.

More specifically, you should design and implement a small database for storing two types of mesh discretizations of geometry domains, as for example used in finite element analysis applications.

This exercise include conceptual modeling using E-R modeling, transformation of the conceptual model into an object-oriented implementation data model and to implement the database by means of a AMOS II DBMS. The implementation should be accompanied by a log of some sample queries listed in the instructions below.

The following steps should be performed:

- E-R modeling
- Transformation to a logical schema
- Implementation
- Defining and testing of query examples

This exercise involves several open design and implementation choices to be decided upon and motivated by the student. Students are free to ask anyone about issues regarding the application part of the exercise, i.e. knowledge about representation of discretized meshes.

This exercise is preferably carried out in groups with two students in each.

1.2 Preparations

Write your solutions on paper before testing them out on the AMOS II system.

The lectures have covered material sufficient for carrying out this exercise. However, to support their decisions throughout the exercise, students may find valuable information in chapters 20, 21 and 22 in the course book and completeing material (slides) from the lectures on object-oriented and object-relational databases systems and query languages.

1.3 Background reading

Read through chapter 20, 21 and 22 in the course book and additional material (slides) from the lectures on object-oriented and object-relational databases systems and query languages.

1.4 Instructions for the assignment

Connect to the course web page and download AMOS II, install the system on your PC. AMOS II is available on the course web at http://user.it.uu.se/~udbl/amos/. The exercise consists of 2 parts:

1) Work through the AMOS II tutorial that is part of the AMOS II archive to download.

2) Develop a scientific database application to handle information regarding scientific data in for plane (2D) discretizations (called a mesh or grid) of geometry domains. Your test data should include at least two different classes of meshes such as bi-linear linear quadrilateral and linear triangular meshes. Additional mesh classes can be selected individually.

A set of example queries should also defined and tested. It is not intended that you should design and implement the basic algorithm for performing the actual discretization. It is the information about factual meshes, such as topology (structure) of the mesh and coordinate information that should be represented.

A specific mesh can be built up by two kinds of basic elements, i.e. bi-linear quadrilateral or linear triangular elements, shown in Figure 2. A specific mesh is constrained to only include one type of elements. The typical structure of such meshes are presented in the examples in Figure 3 and Figure 4.

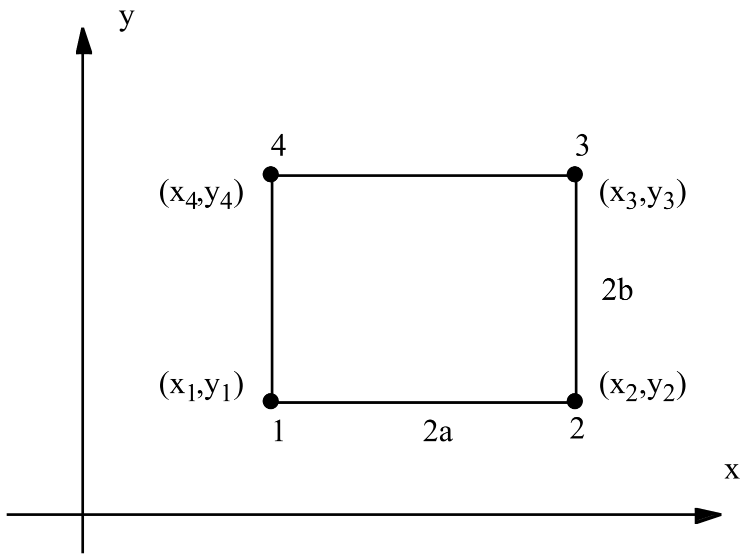
These kinds of discretizations can be viewed as approximation of the geometry. Other physical quantaties can be approximated using the same type of interpolations. For instance, a scalar quantity such as the temperature *T* can be expressed as an interpolated temperature field for a bilinear element as:

$$T = \begin{bmatrix} N_1^e & N_2^e & N_3^e & N_4^e \end{bmatrix} \cdot \begin{bmatrix} T_1 \\ T_1 \\ T_1 \\ T_1 \end{bmatrix}$$

Where N_i^e represent element shape functions that interpolates a field quantity inside the element using nodal point values for the field quantity (here nodal temperatures T_i:s). The shape functions for the bilinear element is given by:

$$N_1^e = \frac{1}{4ab}(x - x_2)(y - y_4)$$
$$N_2^e = -\frac{1}{4ab}(x - x_1)(y - y_3)$$
$$N_3^e = \frac{1}{4ab}(x - x_4)(y - y_2)$$
$$N_4^e = -\frac{1}{4ab}(x - x_3)(y - y_1)$$

This interpolation can be used to represent data (using stored and derived data), for some temperature field of your choice. These representations can later be used to express queries that retrieves field quantities over the geometry. For instance, what is the temperature for a specific coordinate. Observe that these expressions for the bilinear element assume that



element edges are parallell to the coordinate axes as illustrated in Figure 1. There are similar formulations for elements with more general forms as illustrated in Figure 2 but that is outside of this assignment.

Figure 1. Four-node rectangular element (bilinear quadrlateral element)

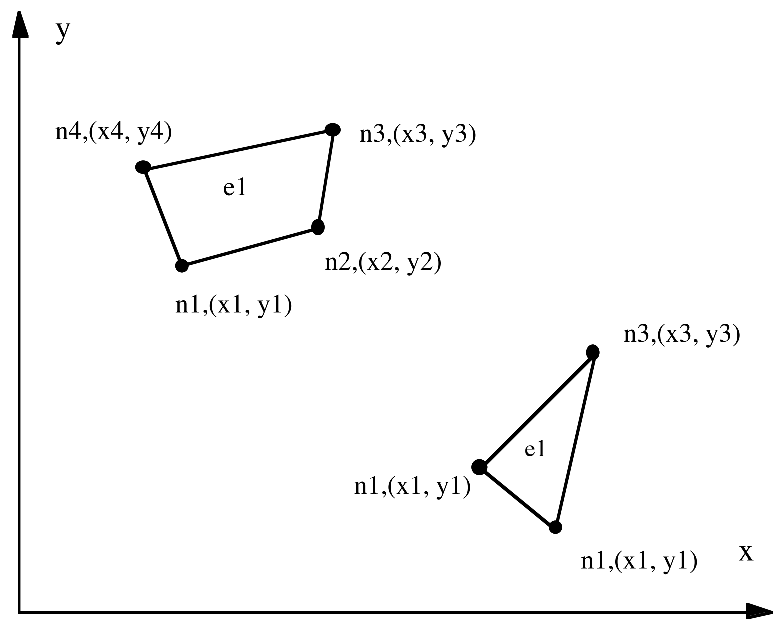


Figure 2. Example of plane 4-node bi-linear quadrilateral and 3-node linear triangular elements.

At least the following concepts should be represented:

- mesh
- element
- node
- coordinate (x- and y-coordinates)
- element numbering
- node numbering (both local and global)

Note that at least global node and element numbers should be able to be altered by a potential external application, e.g. for optimizing the topology of the mesh. This may influence the decision on how to choose keys.

It should be possible to retrieve correct answers to the following queries:

1. What is the coordinate(s) of a specific node?
2. Which are the nodes of a specific element?
3. Which element(s) is a specific node part of?
4. Which nodes are shared by a set of two elements?
5. Which elements are adjacent to a specific element?
6. What is the size of the area of a specific element?
7. What is the size of the area for the complete geometry?
8. What is the opposite edge to a specific element edge (i.e. set of nodes)?
9. What is the complete surrounding edge of the geometry (i.e. a set of edges)?
10. What element is a specific coordinate inside of?
11. What temperature do we have at a specific coordinate (only for the bilinear case)?

Some other interesting queries are welcome. At least two such additional queries should be defined.

Any additional and important assumption or restriction made by the student should be clearly motivated.

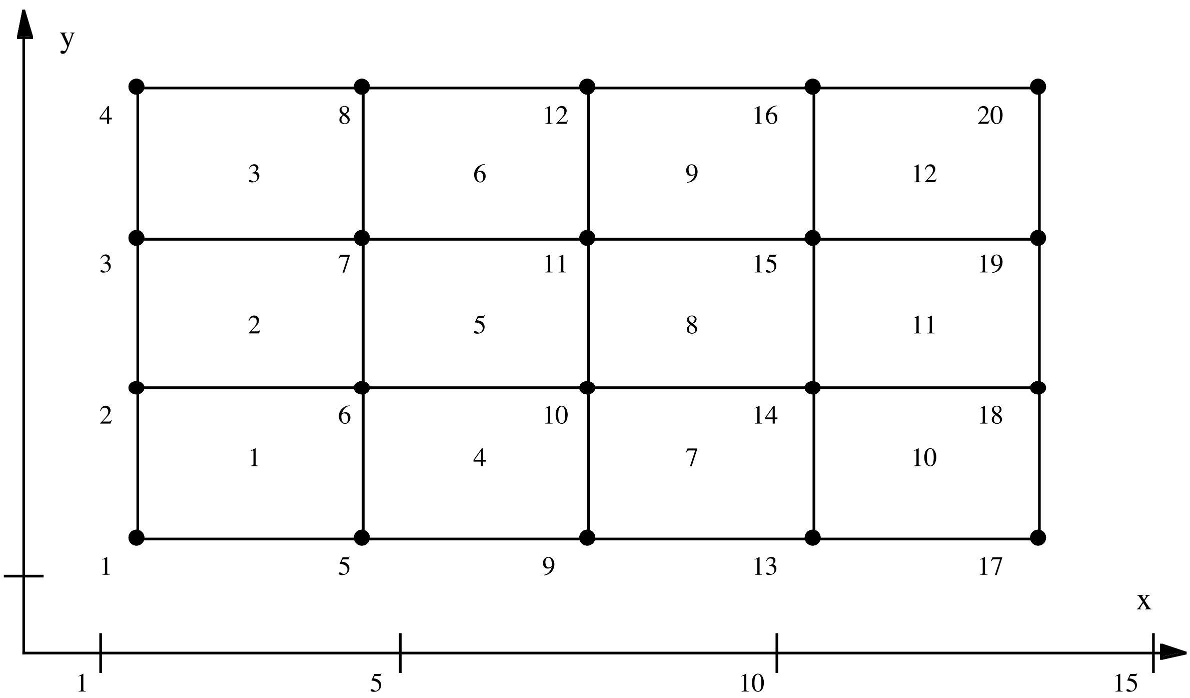


Figure 3. Test examples for a mesh of bi-linear quadrilateral elements including information on global element and node numbers as well as node coordinates.

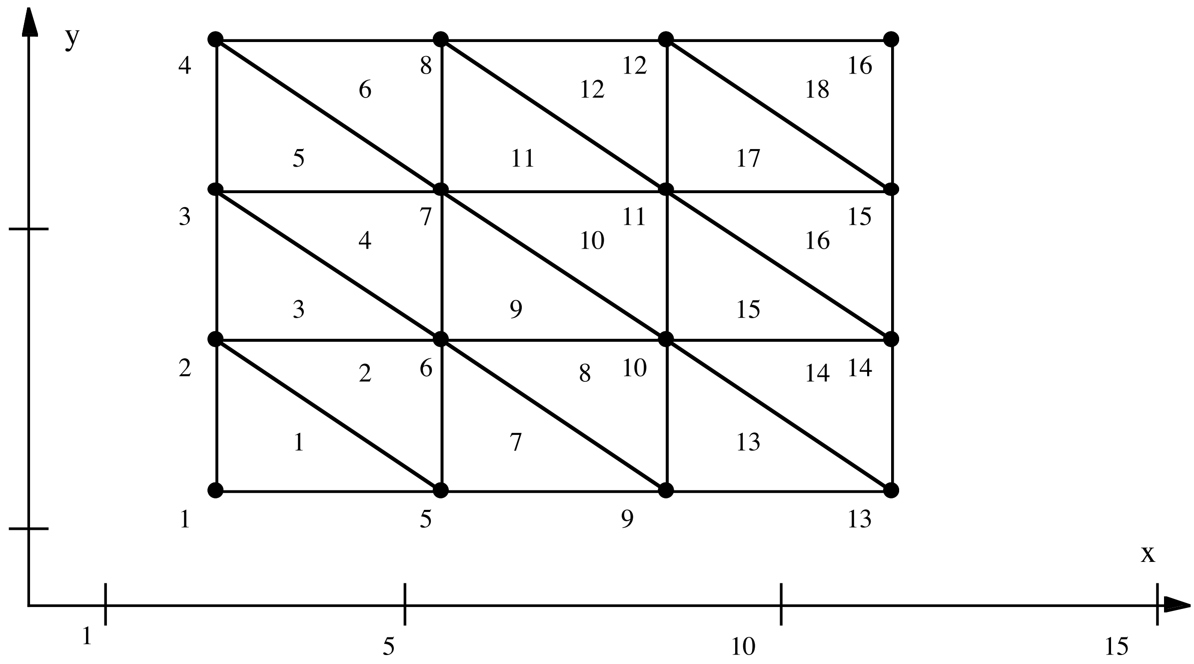


Figure 4. Test examples for a mesh of linear triangular elements including information on global element and node numbers as well as node coordinates.

1.5 Handing in

Hand in an overview of the design, e.g. in an EER diagram, including explanations to concepts and symbols. Solutions to all the questions in the exercise as a printout of the interaction with AMOS II. This can be done by copying the results from the window where you are running AMOS II to a text file that you print out and hand-in to your assistant.

Different design and implementation alternatives and choices, as well as problems or difficulties to perform certain parts of the exercise, should be clearly presented and motivated.