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Abstract

We present an approach to basic arithmetic between abstract matrices, i.e., matrices of symbolic dimension with underspecified components. We define a simple basic function that enables the representation of abstract matrices composed of arbitrary regions in a single term that supports matrix addition and multiplication by regular arithmetic on terms. This can, in particular, be exploited to obtain general arithmetic closure properties for classes of structured matrices. We also describe an approach using alternative basis functions that allow more compact expressions and admit additional arithmetic simplifications.

An abstract matrix is represented as a set of regions, a set of constraints for the variables referred to in these regions, and a (partial) set of bindings for the variables. Two of the variables always present in an abstract matrix is its width and height, although these may or may not have concrete bindings The width and height variables are used to control the various summations in the algorithms for abstract matrix operations.

Introduction :

It is everyday mathematical practice to represent matrices in an abstract way with symbolic dimensions and containing underspecified parts described by the use of ellipses. While reasoning about matrices in this form is mathematically rou- ttime there is very little automated support for it. In earlier work we have investigatedthe problem of representing abstract matrices with certain entries given by expressions and others given by interpolating ellipses [4], [5]. Their analysis in- cluded determining conditions for boundaries between regions and general expressions for elements within regions of such matrices and has led to a representation that made abstract matrices available as a template for concrete matrices with fully specified dimensions and entries.

In this paper we investigate the problem of performingarith- metic on abstract matrices with arbitrary regions of symbolic size. The main challenge is treating the multiple cases that arise when the relation between the sizes of the regions is not known. Consider for example two 2×2 block matrices

of compatible symbolic dimension, for which the sizes of the blocks Ai, Bi are again given symbolically but are not necessarily compatible. That is, the relationship between the horizontal and vertical extensions of the blocks in matrix A to those in matrix B is undefined. Just computing A + B leads to a number of cases for the different possible overlaps of blocks

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Europe (SCIEnce, constract No. 026133). that
can be schematically depicted as:

(a) In a na¨ıve approach we could symbolically represent the sum
as a piecewise function consisting of one case for schema (a), two cases each for (b) and (c), and four cases for (d).

As an effective alternative to this na¨ıve approach we introduce a class of basis functions that enables a straightforward representation of abstract matrices as single sums, where each summand represents one region given as the region entry together with a coefficient consisting of products of basis functions representing the region boundaries. This allows us to
define addition and multiplication for abstract matrices directly via the corresponding operations on the explicit sums. The different cases of how regions can be combined is given as a product of basis functions in a single explicit formula and no longer needs to be considered discretely in a piecewise function.
This gives rise to a natural way of executing matrix operations and we demonstrate how matrix multiplications can effectively be computed symbolically in a form commonly known from textbooks. We will show how our representation allows us to regain information on the structure of a result matrix in a well defined computational manner. This can in

particular be exploited to show general arithmetic closure properties for classes of structured matrices.

There are certain cases in which the na¨ıve, case oriented approach will yield a number of cases factorial in the number of matrix components involved in the computation. In such cases, our approach reduces this to a number of coefficients exponential in the number of components. To address this issue, we present the first steps towards an alternative basis function that, in many cases, reduces this complexity to linear. Our work is related to previous work by Fateman in Macsyma [1], in which indefinite matrices can be subjected to some basic algebraic manipulations. While his matrices are indefinite in size, their elements are fixed to one particular functional expression and cannot be of arbitrary composition. The work is also similar in spirit to earlier work by Watt [6], [7], which presented algorithms for GCD and factorization of polynomials with terms of symbolic degree, as well as to work by Kauers and Schneider [3], [2] on indefinite symbolic summation using unspecified sequences.

Analysis :

Relations can be represented in many ways. Some of which are as follows:

1. Relation as a Matrix: Let P = $[a_1,a_2,a_3,.......a_m]$ and Q = $[b_1,b_2,b_3......b_n]$ are finite sets, containing m and n number of elements respectively. R is a relation from P to Q. The relation R can be represented by m x n matrix M = $[M_{ij}]$, defined as

$$M_{ij} = \begin{cases} 0 & \text{if } (a_i, b_j) \notin R \\ 1 & \text{if } (a_i, b_j) \in R \end{cases}$$

Example

1. Let P = {1, 2, 3, 4}, Q = {a, b, c, d}
2. and R = {(1, a), (1, b), (1, c), (2, b), (2, c), (2, d)}.

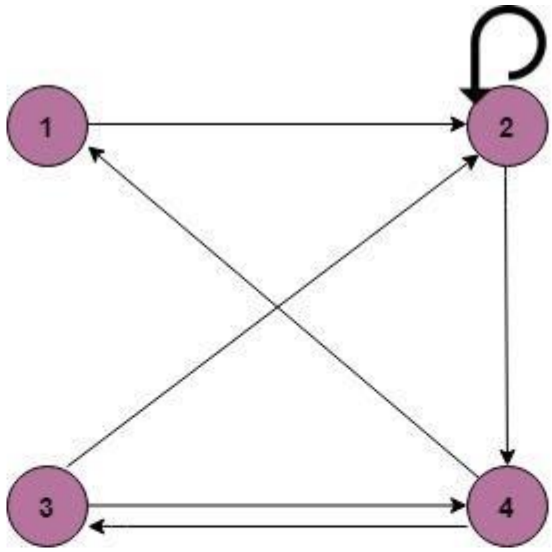
The matrix of relation R is shown as fig:

$$M_R = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \left\{ \begin{array}{cccc} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{array} \right\} \end{array}$$

2. Relation as a Directed Graph: There is another way of picturing a relation R when R is a relation from a finite set to itself.

Example

1. A = {1, 2, 3, 4}
2. R = {(1, 2) (2, 2) (2, 4) (3, 2) (3, 4) (4, 1) (4, 3)}



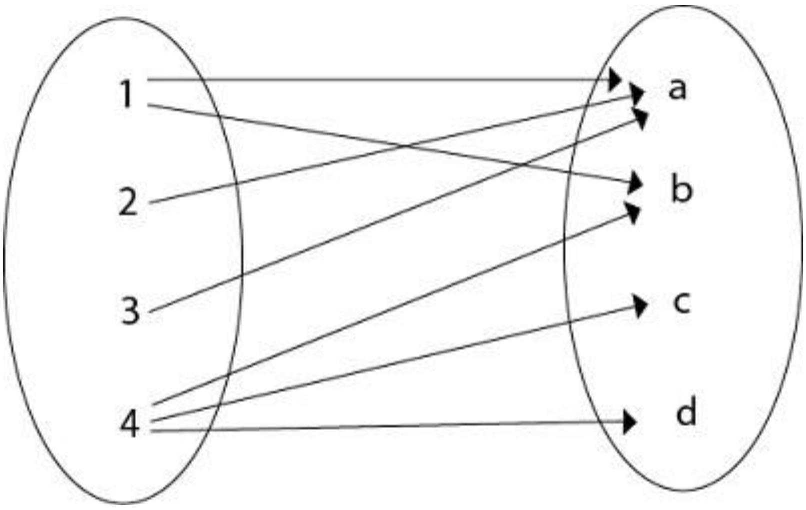
3. **Relation as an Arrow Diagram:** If P and Q are finite sets and R is a relation from P to Q. Relation R can be represented as an arrow diagram as follows.

   Draw two ellipses for the sets P and Q. Write down the elements of P and elements of Q column-wise in three ellipses. Then draw an arrow from the first ellipse to the second ellipse if a is related to b and a ∈ P and b ∈ Q.

   Example

1. Let P = {1, 2, 3, 4}
2. Q = {a, b, c, d}
3. R = {(1, a), (2, a), (3, a), (1, b), (4, b), (4, c), (4, d)}

   The arrow diagram of relation R is shown in fig:



4. **Relation as a Table:** If P and Q are finite sets and R is a relation from P to Q. Relation R can be represented in tabular form.

Make the table which contains rows equivalent to an element of P and columns equivalent to the element of Q. Then place a cross (X) in the boxes which represent relations of elements on set P to set Q.

Example

1. Let P = {1, 2, 3, 4}
2. Q = {x, y, z, k}

3. R = {(1, x), (1, y), (2, z), (3, z), (4, k)}.

The tabular form of relation as shown in fig:

	x	y	z	k
1	x	x		
2			x	
3			x	
4				x

A summary of the essential relationships

The matrix relationships derived in this section are of fundamental importance in the analysis of multi-DOF systems. In view of this, it is perhaps a good idea to run through them once more.

We started with the undamped equations of motion in global coordinates

Conclusion :

In this chapter, the transfer matrix method has been used to efficiently solve the thermo-mechanical problem of simply supported layered plates with thermally and mechanically imperfect interfaces and an arbitrary number of layers. The matrix technique systematizes the analysis and facilitates the solution of the system of algebraic equations resulting from the imposition of continuity and boundary conditions.

The method uses local transfer matrices and continuity conditions at the interfaces to establish explicit matrix relationships between the unknown integration constants in the solution of a generic layer and those of the first layer. In this manner, all field variables in each layer are defined only in terms of the unknown constants of the first layer. Once the integration constants have been derived.

The thermo-elasticity problem of a plate with many layers is reduced to that of a single-layer plate whose solution can be obtained by the imposition of the boundary conditions: the number of equations which needs to be solved becomes independent of the number of layers and is equal to four (two-dimensional problem).

Explicit formulas are presented for the integration constants of the problem. A set of benchmark solutions is presented in tabular and graph forms for plates with different layups, length-to-thickness ratios and interfacial stiffness and thermal resistance, to highlight the efficacy of the method and the important effect of the imperfections on the field variables. Any other desirable benchmark solution can be conveniently generated by the given explicit formulas.

References from :

(i) **Matrix Mathematics: Theory, Facts, and Formulas – Second written by Dennis S. bernsteion.**

(ii) **the theory of matrices by Felix Gantmacher**
matrix algebra websites…