5.3.2 Matrix-matrix multiplication by columns

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Dr. Robert van de Geijn: We're now going to look

at how to more systematically derive the different orderings of the loop

when completing a matrix-matrix multiplication.

Remember that the ij element of C is updated

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Homework 5.3.2.1

1/1 point (graded)

Let A and B be matrices and AB be well-defined and let B have at least four columns. The first and the fourth column of B are the same.

The first and fourth columns of AB are the same.

Always ▾ ✔ **Answer:** Always

Explanation

Transcripted in final section of this week

Answer: Always

Partition

$$B = \left(\begin{array}{c|c|c|c|c} b_0 & b_1 & b_2 & b_3 & B_4 \end{array} \right),$$

where B_4 represents the part of the matrix to the right of the first four columns. Then

$$AB = A \left(\begin{array}{c|c|c|c|c} b_0 & b_1 & b_2 & b_3 & B_4 \end{array} \right) = \left(\begin{array}{c|c|c|c|c} Ab_0 & Ab_1 & Ab_2 & Ab_3 & AB_4 \end{array} \right).$$

Now, if $b_0 = b_3$ then $Ab_0 = Ab_3$ and hence the first and fourth columns of AB are equal.

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Answers are displayed within the problem

Homework 5.3.2.2

1/1 point (graded)

Let A and B be matrices and AB be well-defined and let A have at least four columns. The first and fourth columns of A are the same.

The first and fourth columns of AB are the same.

Sometimes ▾ ✔ **Answer:** Sometimes

Explanation

Answer: Sometimes To find an example where the statement is *true*, we first need to make sure that the result has at least four columns, which means that B must have at least four columns. Then an example when the statement is *true*: $A = 0$ (the zero matrix) or $B = I$ (the identity matrix of size at least 4×4).
An example when it is *false*: Almost any matrices A and B. For example:

$$A = \begin{pmatrix} 0 & 1 & 2 & 0 \\ 0 & 1 & 2 & 0 \end{pmatrix}, \quad B = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

so that

$$AB = \begin{pmatrix} 0 & 1 & 2 & 0 \\ 0 & 1 & 2 & 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 0 & 1 & 2 & 2 \\ 0 & 1 & 2 & 2 \end{pmatrix}.$$

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Homework 5.3.2.3

18/18 points (graded)

Compute each of the following matrix-matrix multiplications:

$$\begin{pmatrix} 1 & -2 & 2 \\ -1 & 2 & 1 \\ 0 & 1 & 2 \end{pmatrix} \left(\left. \begin{array}{|r|} -1 \\ 2 \\ 1 \end{array} \right. \quad\quad\quad \right)$$

$=$

-3 Answer: -3

6 Answer: 6

4 Answer: 4

$$\begin{pmatrix} 1 & -2 & 2 \\ -1 & 2 & 1 \\ 0 & 1 & 2 \end{pmatrix} \left(\begin{array}{r|r|c} -1 & 0 & \\ 2 & 1 & \\ 1 & -1 & \end{array} \right)$$

$=$

-3 Answer: -3

-4 Answer: -4

6 Answer: 6

1 Answer: 1

4 Answer: 4

-1 Answer: -1

$$\begin{pmatrix} 1 & -2 & 2 \\ -1 & 2 & 1 \\ 0 & 1 & 2 \end{pmatrix} \left(\begin{array}{rr|r|} -1 & 0 & 1 \\ 2 & 1 & -1 \\ 1 & -1 & 2 \end{array} \right)$$

-3	-4	7
✔ **Answer:** -3	✔ **Answer:** -4	✔ **Answer:** 7
6	1	-1
✔ **Answer:** 6	✔ **Answer:** 1	✔ **Answer:** -1
4	-1	3
✔ **Answer:** 4	✔ **Answer:** -1	✔ **Answer:** 3

$$\left(\begin{array}{rrr} 1 & -2 & 2 \\ -1 & 2 & 1 \\ 0 & 1 & 2 \end{array}\right)\left(\begin{array}{|r|cc} -1 & & \\ 2 & & \\ 1 & & \end{array}\right) = \left(\begin{array}{|r|cc} -3 & & \\ 6 & & \\ 4 & & \end{array}\right)$$

$$\left(\begin{array}{rrr} 1 & -2 & 2 \\ -1 & 2 & 1 \\ 0 & 1 & 2 \end{array}\right)\left(\begin{array}{r|r|c} -1 & 0 & \\ 2 & 1 & \\ 1 & -1 & \end{array}\right) = \left(\begin{array}{r|r|c} -3 & -4 & \\ 6 & 1 & \\ 4 & -1 & \end{array}\right)$$

$$\left(\begin{array}{rr|r|} 1 & -2 & 2 \\ -1 & 2 & 1 \\ 0 & 1 & 2 \end{array}\right)$$

$$\left(\begin{array}{rrr} 1 & -2 & 2 \\ -1 & 2 & 1 \\ 0 & 1 & 2 \end{array}\right)\left(\begin{array}{rr|r|} -1 & 0 & 1 \\ 2 & 1 & -1 \\ 1 & -1 & 2 \end{array}\right) = \left(\begin{array}{rr|r|} -3 & -4 & 7 \\ 6 & 1 & -1 \\ 4 & -1 & 3 \end{array}\right)$$

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Answers are displayed within the problem

Homework 5.3.2.4

1/1 point (graded)

Algorithm: $C := \text{GEMM\_UNB\_VAR1}(A, B, C)$

Partition $B \rightarrow \left(B_L \,\middle|\, B_R \right)$, $C \rightarrow \left(C_L \,\middle|\, C_R \right)$
  where B_L has 0 columns, C_L has 0 columns

while $n(B_L) < n(B)$ **do**

  Repartition

$$\left(B_L \,\middle|\, B_R \right) \rightarrow \left(B_0 \,\middle|\, b_1 \,\middle|\, B_2 \right), \left(C_L \,\middle|\, C_R \right) \rightarrow \left(C_0 \,\middle|\, c_1 \,\middle|\, C_2 \right)$$

  where b_1 has 1 column, c_1 has 1 column

  $c_1 := A b_1 + c_1$

  Continue with

$$\left(B_L \,\middle|\, B_R \right) \leftarrow \left(B_0 \,\middle|\, b_1 \,\middle|\, B_2 \right), \left(C_L \,\middle|\, C_R \right) \leftarrow \left(C_0 \,\middle|\, c_1 \,\middle|\, C_2 \right)$$

endwhile

Write the routine

- `[ C_out ] = Gemm_unb_var1( A, B, C )`

that computes $C := AB + C$ using the above algorithm.

Some links that will come in handy:

- Spark (alternatively, open the file `LAFF-2.0xM -> Spark -> index.html`)
- PictureFLAME (alternatively, open the file `LAFF-2.0xM -> PictureFLAME -> PictureFLAME.html`)

The update $c_1 := Ab_1 + c_1$ can be accomplished by the call to

```
laff_gemv( 'No transpose', 1, ..., ...., 1, .... )
```

(click on the "laff routines" tab at the top of the page for more info).

You may want to use the following script to test your implementations:

- test_Gemm_unb_var1.m

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Gemm_unb_var1.m

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