

# Program 1 - matrices

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**Due** Tuesday by 1:59am      **Points** 160      **Submitting** a file upload  
**Available** until Apr 26 at 1:59am

## Program 1 – CS 344

This assignment asks you to write bash shell scripts to compute matrix operations. The purpose is to get you familiar with the Unix shell, shell programming, Unix utilities, standard input, output, and error, pipelines, process ids, exit values, and signals (at a basic level).

What you're going to submit is your script, called simply "matrix".

## Overview

In this assignment, you will write a bash shell script that calculates basic matrix operations using input from either a file or stdin. The input will be whole number values separated by tabs into a rectangular matrix. Your script should be able to print the dimensions of a matrix, transpose a matrix, calculate the mean vector of a matrix, add two matrices, and multiply two matrices.

You will be using bash builtins and Unix utilities to complete the assignment. Some commands to read up on are `while`, `cat`, `read`, `expr`, `cut`, `head`, `tail`, `wc`, and `sort`.

Your script must be called simply "matrix". The general format of the matrix command is:

```
matrix OPERATION [ARGUMENT]...
```

Refer to [man\(1\)](#) for an explanation of the conventional notation regarding command syntax, to understand the line above. Note that many terminals render italic font style as an underline:

```
matrix OPERATION [ARGUMENT]...
```

## Specifications

Your program must perform the following operations: dims, transpose, mean, add, and multiply. Usage is as follows:

```
matrix dims [MATRIX]
matrix transpose [MATRIX]
matrix mean [MATRIX]
matrix add MATRIX_LEFT MATRIX_RIGHT
matrix multiply MATRIX_LEFT MATRIX_RIGHT
```

The `dims`, `transpose`, and `mean` operations should either perform their respective operations on the file named *MATRIX*, or on a matrix provided via `stdin`. The `add` and `multiply` operations do not need to process input via `stdin`.

- `dims` should print the dimensions of the matrix as the number of rows, followed by a space, then the number of columns.
- `transpose` should reflect the elements of the matrix along the main diagonal. Thus, an  $M \times N$  matrix will become an  $N \times M$  matrix and the values along the main diagonal will remain unchanged.
- `mean` should take an  $M \times N$  matrix and return an  $1 \times N$  row vector, where the first element is the mean of column one, the second element is the mean of column two, and so on.
- `add` should take two  $M \times N$  matrices and add them together element-wise to produce an  $M \times N$  matrix. `add` should return an error if the matrices do not have the same dimensions.
- `multiply` should take an  $M \times N$  and  $N \times P$  matrix and produce an  $M \times P$  matrix. Note that, unlike addition, matrix multiplication is not commutative. That is  $A \cdot B \neq B \cdot A$ .

Here is a brief example of what the output should look like.

```
$ cat m1
1      2      3      4
5      6      7      8
$ cat m2
1      2
3      4
5      6
7      8
$ ./matrix dims m1
2 4
$ cat m2 | ./matrix dims
4 2
$ ./matrix add m1 m1
2      4      6      8
10     12     14     16
$ ./matrix add m2 m2
2      4
6      8
10     12
14     16
$ ./matrix mean m1
3      4      5      6
$ ./matrix transpose m1
1      5
2      6
3      7
4      8
$ ./matrix multiply m1 m2
50     60
114    140
```

You must check for the right number and format of arguments to `matrix`. This means that, for example, you must check that a given input file is readable, before attempting to read it. You are not required to test if the

input file *itself* is valid. In other words, the behavior of matrix is undefined when the matrix input is not a valid matrix. for the purposes of this assignment, a valid matrix is a tab-delimited table containing at least one element, where each element is a signed integer, every entry is defined, and the table is rectangular.

The following are examples of invalid matrices and will not be tested against your code, and may *not* be output by your program:

- An empty matrix.
- A matrix where the final entry on a row is followed by a tab character.
- A matrix with empty lines.
- A matrix with any element that is blank or not an integer.

Here is a valid matrix file, m1:

```
$ cat m1
8      5      6
3      2      2
1      6      7
5      0      7
2      2      4
$ cat -A m1 # The '-A' flag shows tabs as '^I' and newlines as '$'. This is a good way to check correctness.
8^I5^I6$
3^I2^I2$
1^I6^I7$
5^I0^I7$
2^I2^I4$
$
```

If the inputs are valid -- your program should output only to stdout, and nothing to stderr. The return value should be 0.

If the inputs are invalid -- your program should output only to stderr, and nothing to stdout. The return value should be any number except 0. The error message you print is up to you; you will receive points as long as you print *something* to stderr and return a non-zero value.

Your program will be tested with matrices up to dimension 100 x 100.

Though optional, I do recommend that you use temporary files; arrays are not recommended. For this assignment, any temporary files you use should be put in the current working directory. (A more standard place for temporary files is in /tmp but don't do that for this assignment; it makes grading easier if they are in the current directory.) *Be sure any temporary file you create uses the process id as part of its name, so that there will not be conflicts if the program is running more than once.* Be sure you remove any temporary files when your program is done. You should also use the trap command to catch interrupt, hangup, and terminate signals to remove the temporary files if the program is terminated unexpectedly.

All values and results are and must be integers. You may use the `expr` command to do your calculations, or any other bash shell scripting method, such as `((expr))`. Do not use any other languages other than bash shell scripting: this means that, among others, awk, sed, tcl, bc, perl, & the python languages and tools are

off-limits for this assignment. Note that `expr` only works with whole numbers. When you calculate the average you must round to the nearest integer, where half values round away from 0 (i.e. 7.5 rounds up to 8, but -7.5 rounds down to -8). This is the most common form of rounding. When doing truncating integer division (as bash does), this formula works to divide two numbers and end up with the proper rounding:

```
(a + (b/2)*( (a>0)*2-1 )) / b
```

You can learn more about rounding methods here:

[Rounding – Wikipedia](https://en.wikipedia.org/wiki/Rounding#Round_half_away_from_zero) [\(https://en.wikipedia.org/wiki/Rounding#Round\\_half\\_away\\_from\\_zero\)](https://en.wikipedia.org/wiki/Rounding#Round_half_away_from_zero)

## Grading With a Script

To make it easy to see how you're doing, you can download the actual grading script here:

[p1gradingscript](#)

This script is very close to the one that will be used to assign your script a grade. To use the script, just place it in the same directory as your matrix script and run it like this:

```
$ ./p1gradingscript
```

Be aware that this script might take a minute or two to run, depending on how speedy your algorithms and code are, since there's a lot of matrix math in there. You're not penalized for having a long-running script, though the TAs may decide that it's just stuck in a loop and is actually broken if it goes too much longer than that (which is a penalizing problem). If you have any doubt about your running time being acceptable, just add a note into your code as a comment at the top to warn the TA. When we run your script for grading, we will do this to put your results into a file we can examine more easily:

```
$ ./p1gradingscript > grading_result.username
```

To compare yours to a perfect solution, you can download here a completely correct run of my script that shows what you should get if everything is working correctly:

[p1perfectoutput](#)

The p1gradingscript itself is a good resource for seeing how some of the more complex shell scripting commands work, too.

## Summary

Your script must support the following operations:

- **matrix dims [MATRIX]**
  - Prints error message to stderr, nothing to stdout and return value != 0 if:
    - Argument count is greater than 1 (e.g. ``matrix dims m1 m2``).
    - Argument count is 1 but the file named by argument 1 is not readable (e.g. ``matrix dims no_such_file``).

- Otherwise, prints "ROWS COLS" (Space separated!) to stdout, nothing to stderr, and returns 0.
- **matrix transpose** [MATRIX]
  - Prints error message to stderr, nothing to stdout and return value != 0 if:
    - Argument count is greater than 1 (e.g. ``matrix transpose m1 m2``).
    - Argument count is 1 but the file named by argument 1 is not readable (e.g. ``matrix transpose no_such_file``).
  - Otherwise, prints the transpose of the input, in a valid matrix format to stdout, nothing to stderr, and returns 0.
- **matrix mean** [MATRIX]
  - Prints error message to stderr, nothing to stdout and return value != 0 if:
    - Argument count is greater than 1 (e.g. ``matrix mean m1 m2``).
    - Argument count is 1 but the file named by argument 1 is not readable (e.g. ``matrix mean no_such_file``).
  - Otherwise, prints a row vector mean of the input matrix, in a valid matrix format to stdout, nothing to stderr, and returns 0. All values must round to the nearest integer, with `***.5` values rounded away from zero.
- **matrix add** MATRIX\_LEFT MATRIX\_RIGHT
  - Prints error message to stderr, nothing to stdout and return value != 0 if:
    - Argument count does not equal 2 (e.g. ``matrix add m1 m2 m3`` or ``matrix add m1``).
    - Argument count is 2 but the file named by either argument is not readable (e.g. ``matrix add m1 no_such_file``).
    - The dimensions of the input matrices do not allow them to be added together following the rules of matrix addition.
  - Otherwise, prints the sum of both matrices, in a valid matrix format to stdout, nothing to stderr, and returns 0.
- **matrix multiply** MATRIX\_LEFT MATRIX\_RIGHT
  - Prints error message to stderr, nothing to stdout and return value != 0 if:
    - Argument count does not equal 2 (e.g. ``matrix multiply m1 m2 m3`` or ``matrix multiply m1``).
    - Argument count is 2 but the file named by either argument is not readable (e.g. ``matrix multiply m1 no_such_file``).
    - The dimensions of the input matrices do not allow them to be multiplied together following the rules of matrix multiplication.
  - Otherwise, prints the product of both matrices, with the first argument as the left matrix and the second argument as the right matrix, in a valid matrix format to stdout, nothing to stderr, and returns 0. (``matrix multiply A B`` should return `A*B`, not `B*A`)

An invalid command must result in an error message to stderr, nothing to stdout, and a return value != 0.

## Hints

Try writing each part as a separate function (see the [1.4 bash Functions](#) reading). You can use `$1` `"${@:2}"` to call the function named by argument 1, with the remaining arguments passed to it. For example, `matrix multiply m1 m2` will expand `$1 "${@:2}"` to `multiply m1 m2` inside your script, which will call the function named "multiply".

You'll need to use the `read` command extensively to read in data from a file. Note that it reads in one line at a time *from the stdin buffer* and stores the line in a variable called `REPLY`, unless specified. Generally, `read` is used in a while loop, where a file is redirected to stdin *of the while loop*. Calling `read < myfile` multiple times will repeatedly read the *first* line of `myfile`.

The `expr` command and the shell can have conflicts over special characters. If you try `expr 5 * ( 4 + 2 )`, the shell will think `*` is a filename wild card and the parentheses mean command grouping. You have to use

backslashes, like this:

```
expr 5 \* \( 4 + 2 \)
```

I **highly** recommend that you develop this program directly on the class server (os1). Doing so will prevent you from having problems transferring the program back and forth, which can cause compatibility issues. Keep in mind that students caught developing on flip risk losing points on the assignment.

If you are using Windows as your operating system, windows may replace newlines in files with newline-carriage returns. These will be displayed as ^M characters in vim. To remove them, use the utility `dos2unix`.

```
% dos2unix bustedFile
```

## What to Turn in and When

Simply submit your "matrix" script file. Your script must be entirely contained in this one file. Do not split this assignment into multiple files or programs. As our Syllabus says, please be aware that neither the Instructor nor the TA(s) are alerted to comments added to the text boxes in Canvas that are alongside your assignment submissions, and they may not be seen. No notifications (email or otherwise) are sent out when these comments are added, so we aren't aware that you have added content! If you need to make a meta-comment about this assignment, please include it in a #comment near the top of the script itself, or email the person directly who will be grading it (see the [Home](#) page for grading responsibilities).

The due date given below is the last minute that this can be turned in for full credit. The "available until" date is NOT the due date, but instead closes off submissions for this assignment automatically once 48 hours past the due date has been reached, in accordance with our [Syllabus Grading Policies](#).

## Grading

148 points are available for your script (which is the only file you'll submit) successfully passing the grading script, while the final 12 points will be based on your style, readability, and commenting. Comment well, often, and verbosely: we want to see that you are telling us WHY you are doing things, in addition to telling us WHAT you are doing.

The TAs will use this exact set of instructions: [Program1 Grading.pdf](#)  to grade your submission.

### Test Rubric

Criteria	Ratings		Pts
Grading Script Total	148.0 to >0.0 pts Total Points	0.0 pts No Marks	148.0 pts
Comments and Code Style	12.0 to >0.0 pts Full Marks	0.0 pts No Marks	12.0 pts
Late	0.0 pts Not Late	-16.0 pts Late	0.0 pts
Late > 24 hours	0.0 pts Not Late > 24 hours	-24.0 pts Late > 24 hours	0.0 pts
Total Points: 160.0			