MathLight

A lightweight matrix manipulation language

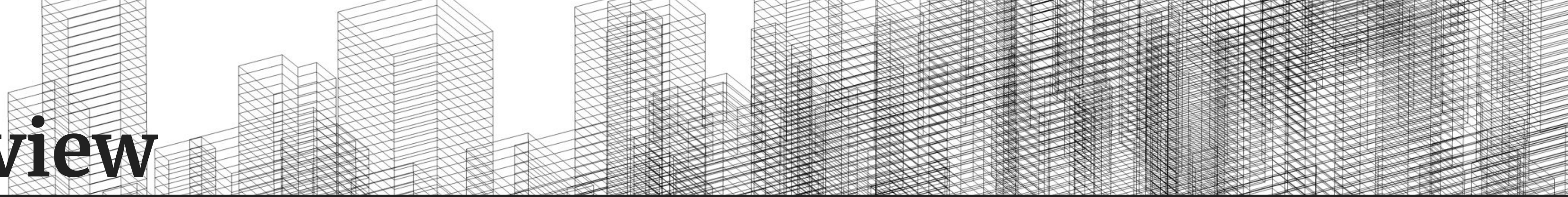
Boya Song (bs3065) Chunli Fu(cf2710)
Mingye Chen (mc4414) Yuli Han(yh2986)

Motivation

- Increasing and common usage of matrices.
- Matlab: expensive, not lightweight enough
- make it as an easy, fast and flexible language and the basic syntax is similar to C.

Goal

- Design an imperative language with matrix manipulations.
- Matrix data type with convenient matrix operations.
- Rich matrix related built-in functions.

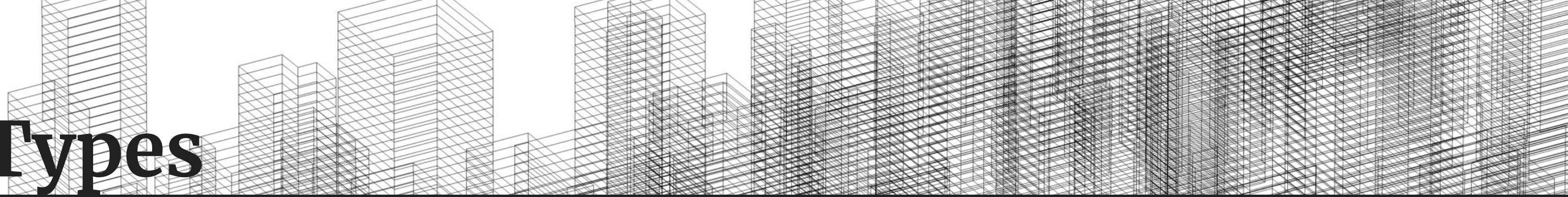


Overview

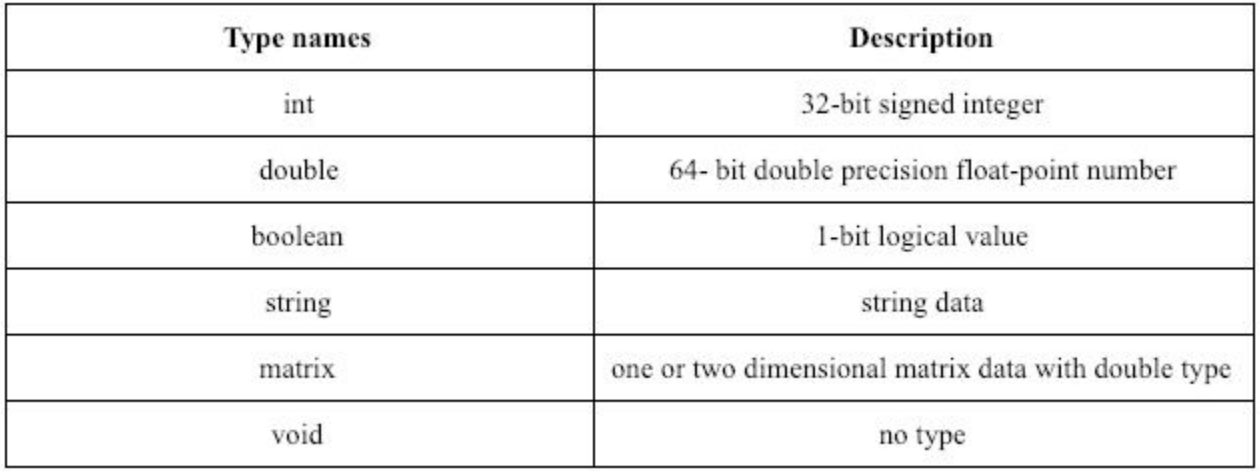
- C-like syntax
- New data type:

  matrix with powerful matrix-related

  operations and built-in functions
- Imperative
- Static scope
- Statically-typed



Data Types



Type names	Description
int	32-bit signed integer
double	64- bit double precision float-point number
boolean	1-bit logical value
string	string data
matrix	one or two dimensional matrix data with double type
void	no type

Matrix Literal

matrix m<2,2> = [1,2;3,4]; $\Rightarrow$ $\begin{bmatrix} 1.0 & 2.0 \\ 3.0 & 4.0 \end{bmatrix}$

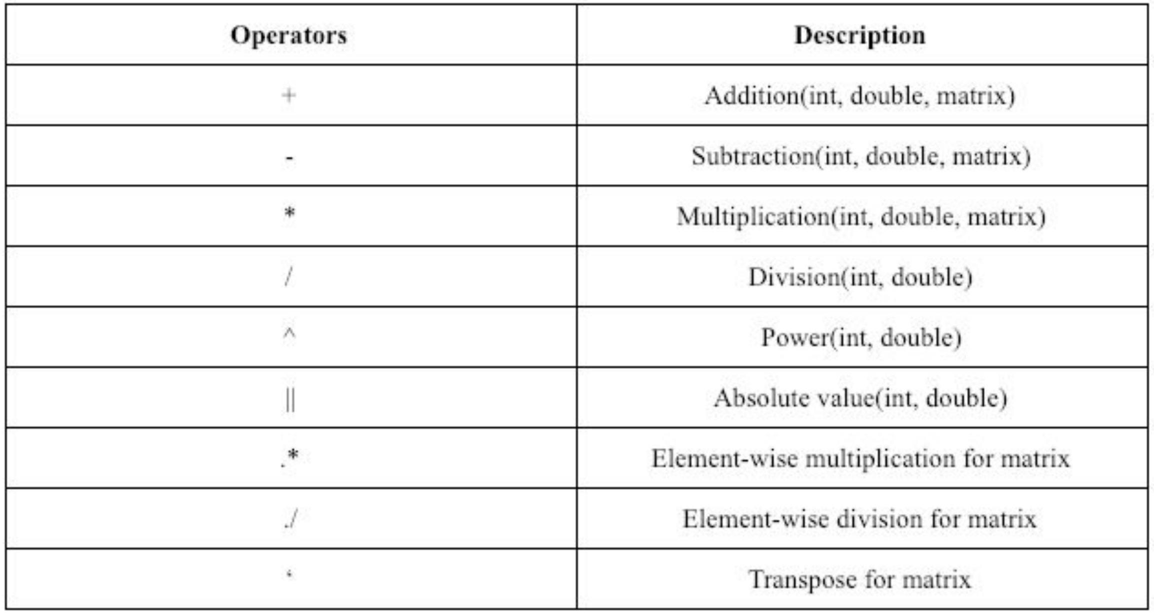
Declare

```
int a;
matrix b<2,3>;
matrix b<5>;
```

Declare & Assign

```
int a = 0;

matrix b<2,3> = [1,2,3;3,4,4];

matrix c<5> = [1,2,3,4,5];

matrix d<2,2> = fill(2,2,3.0);
```

Arithmetic Operators & Built-in Functions

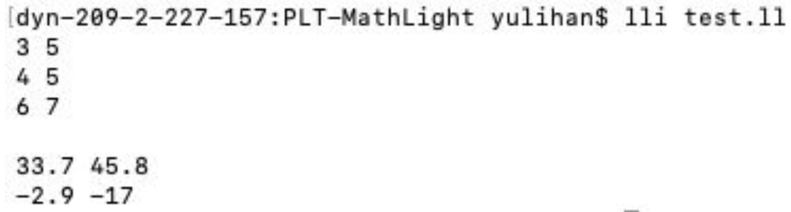


Operators	Description
+	Addition(int, double, matrix)
-	Subtraction(int, double, matrix)
*	Multiplication(int, double, matrix)
/	Division(int, double)
^	Power(int, double)
||	Absolute value(int, double)
.*	Element-wise multiplication for matrix
./	Element-wise division for matrix
‘	Transpose for matrix

int		int
double	+	double
double		int
int	−	double
double		matrix
matrix	×	double
int		matrix
matrix		int
matrix		matrix

Arithmetic Operators & Built-in Functions

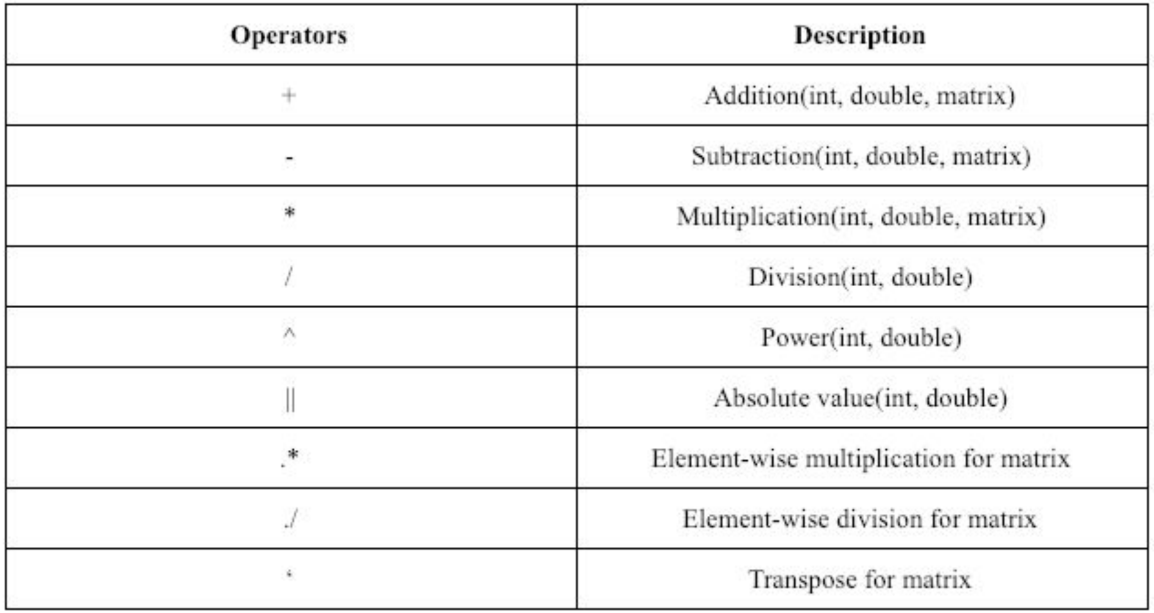
```
func int main() {
        int a = 1;
        double b = 2.5;
        matrix c<2,3> = [2.3,4.2,3.3;-7.6,-3.4,4.5];
        matrix d<3,2> = [2,4;3,4;5,6];
        print(a + d);
        print("");
        print(c * d);
        return 0;
}
```



```
[dyn-209-2-227-157:PLT-MathLight yulihan$ lli test.ll
3 5
4 5
6 7

33.7 45.8
-2.9 -17
```

int		int
double	+	double
double		int
int	−	double
double		matrix
matrix	×	double
int		matrix
matrix		int

Arithmetic Operators & Built-in Functions



Operators	Description
+	Addition(int, double, matrix)
-	Subtraction(int, double, matrix)
*	Multiplication(int, double, matrix)
/	Division(int, double)
^	Power(int, double)
||	Absolute value(int, double)
.*	Element-wise multiplication for matrix
./	Element-wise division for matrix
‘	Transpose for matrix

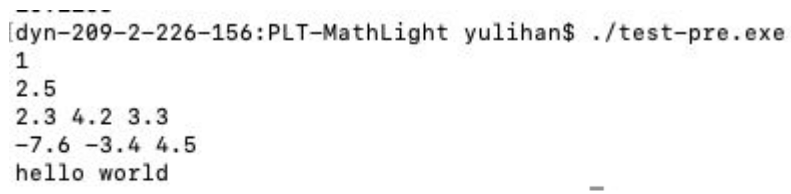
int		int
double	+	double
double		int
int	−	double
double		matrix
matrix	×	double
int		matrix
matrix		int

Arithmetic Operators & Built-in Functions

General built-in functions:

print : support printing for int, double, string and matrix

sqrt(int a)/sqrt(double a)   log(int a)/log(double a)



```
[dyn-209-2-226-156:PLT-MathLight yulihan$ ./test-pre.exe
1
2.5
2.3 4.2 3.3
-7.6 -3.4 4.5
hello world
```

```
func int main() {
    int a=1;
    double b = 2;
    matrix c<2,3> = [2.3,4.2,3.3;-7.6,-3.4,4.5];
    string s = “hello world”;
    print(a);
    print(b);
    print(c);
    print(s);
    return 0;
}
```

Arithmetic Operators & Built-in Functions

matrix-related built-in functions:

inv(matrix m): inverse matrix det(matrix m): determinant

fill(int r, int c, double value): initialize matrix with given size and given default value

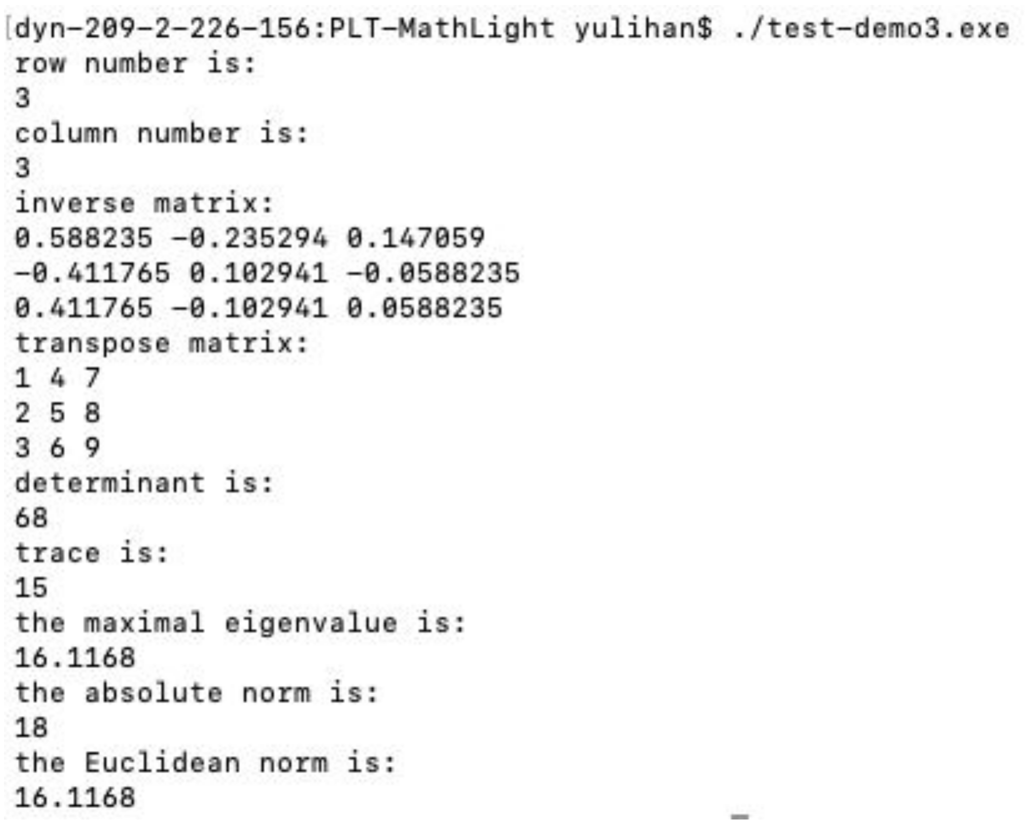
Other built-in functions: size, Euclidean norm, absolute norm, sum, mean, trace, max eigenvalue...

Arithmetic Operators & Built-in Functions

```
func int main(){
  matrix a<3,3> = [1,2,3;4,5,6;7,8,9];
  print("row number is:");
  print(sizeof_row(a));
  print("column number is:");
  print(sizeof_col(a));
  print("inverse matrix:");
  print(inv(a));
  print("transpose matrix:");
  print(a');
  print("determinant is:");
  print(det(a));
```

```
  print("trace is:");
  print(tr(a));
  print("the maximal eigenvalue is:");
  print(max_eigvalue(a));
  print("the absolute norm is:");
  print(norm1(a));

  print("the Euclidean norm is:");
  print(norm2(a));

  return 0;
}
```

Arithmetic Operators & Built-in Functions



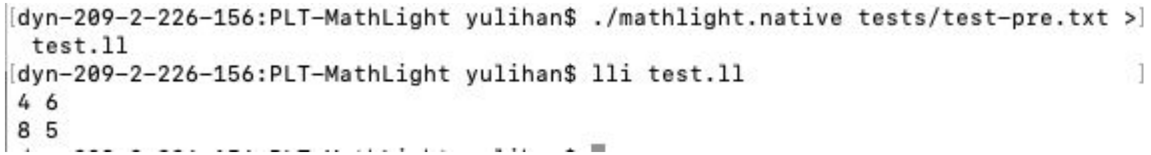
```
dyn-209-2-226-156:PLT-MathLight yulihan$ ./test-demo3.exe
row number is:
3
column number is:
3
inverse matrix:
0.588235 -0.235294 0.147059
-0.411765 0.102941 -0.0588235
0.411765 -0.102941 0.0588235
transpose matrix:
1 4 7
2 5 8
3 6 9
determinant is:
68
trace is:
15
the maximal eigenvalue is:
16.1168
the absolute norm is:
18
the Euclidean norm is:
16.1168
```

matrix a<3,3>

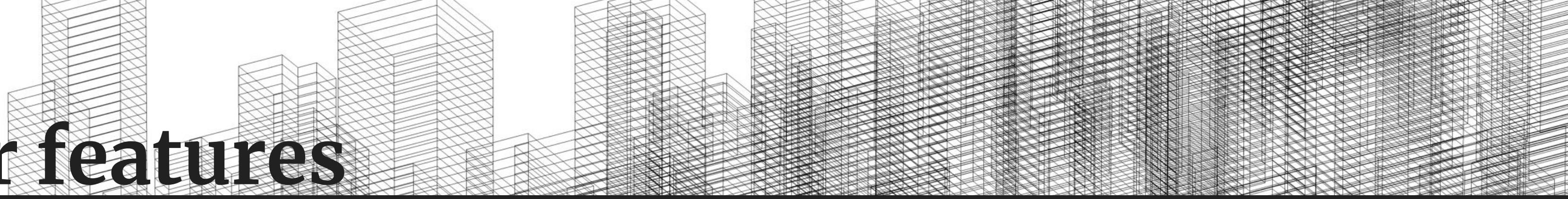
1 2 3
4 5 6
7 8 9

Function Declaration

```
func matrix mat_add(matrix a, matrix b) {
        return a+b;
}

func int main() {
        matrix a<2,2> = [1,3;5,2];
        matrix b<2,2> = fill(2,2,3.0);
        print(mat_add(a, b));
        return 0;
}
```



```
dyn-209-2-226-156:PLT-MathLight yulihan$ ./mathlight.native tests/test-pre.txt >
 test.ll
dyn-209-2-226-156:PLT-MathLight yulihan$ lli test.ll
4 6
8 5
```



Other features

- Support both vectors and matrices.

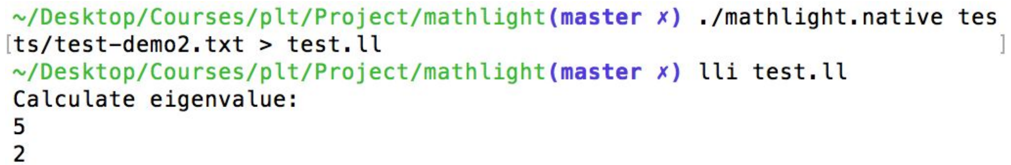
  matrix a<3> = [1,2,3];

- Matrix concatenation

  matrix a <2, 3> = [b ; c];
  matrix a <2, 3> = [b, c];

- Int to double casting.

```
int a = 1;
double b = 2.0;
double res = a + b;
```

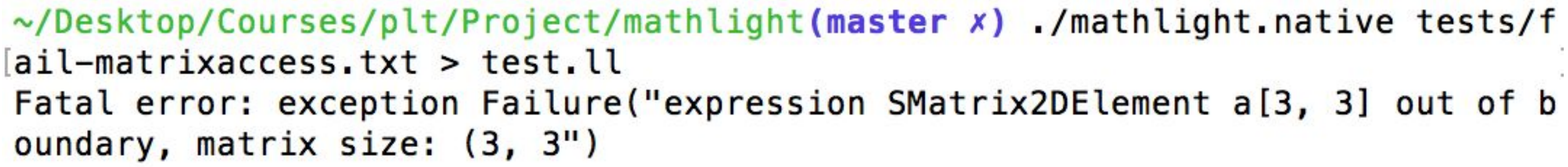


```
~/Desktop/Courses/plt/Project/mathlight(master ✗) ./mathlight.native tes
ts/test-demo2.txt > test.ll
~/Desktop/Courses/plt/Project/mathlight(master ✗) lli test.ll
Calculate eigenvalue:
5
2
```

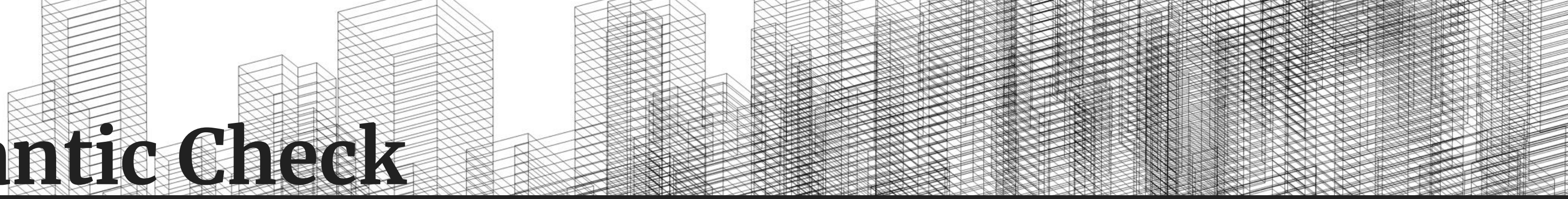
```
func int main(){
  matrix col1 <2, 1> = [3.0; 1.0];
  matrix col2 <2, 1> = [2.0; 4.0];
  matrix arr <2,2> = [col1, col2];
  int a = 1;
  double b = -arr[0,0] - arr[1,1];
  double c = arr[0,0] * arr[1,1] - arr[0,1] * arr[1,0];
  double eigv1 = ( -b + sqrt(b*b - 4 * a * c)) / (2 * a);
  double eigv2 = ( -b - sqrt(b*b - 4 * a * c)) / (2 * a);

  print("Calculate eigenvalue:");
  print(eigv1);
  print(eigv2);
  return 0;
}
```

Semantic Check

```
func int main() {
  matrix a <3, 3>;
  a = [1.1, 2.1, 3.1; 1.0, 2.0, 3.0; 4.1, 4.2, 4.3];
  print(a[3,3]);
  return 0;
}
```

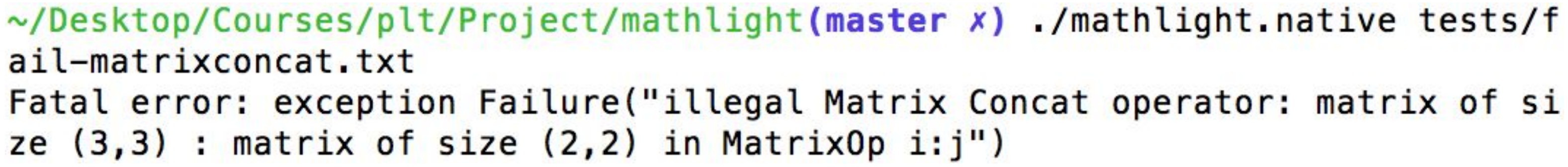


```
~/Desktop/Courses/plt/Project/mathlight(master ✗) ./mathlight.native tests/f
ail-matrixaccess.txt > test.ll
Fatal error: exception Failure("expression SMatrix2DElement a[3, 3] out of b
oundary, matrix size: (3, 3")
```



Semantic Check

```
func int main () {
    matrix i <3, 3>;
    matrix j <2, 2>;
    i = [1.0,2.0,3.0;1.0,2.0,3.0];
    j = [4.0,5.0;4.0,5.0];
    print(i);
    print([i; j]);
    return 0;
}
```



```
~/Desktop/Courses/plt/Project/mathlight(master ✗) ./mathlight.native tests/f
ail-matrixconcat.txt
Fatal error: exception Failure("illegal Matrix Concat operator: matrix of si
ze (3,3) : matrix of size (2,2) in MatrixOp i:j")
```

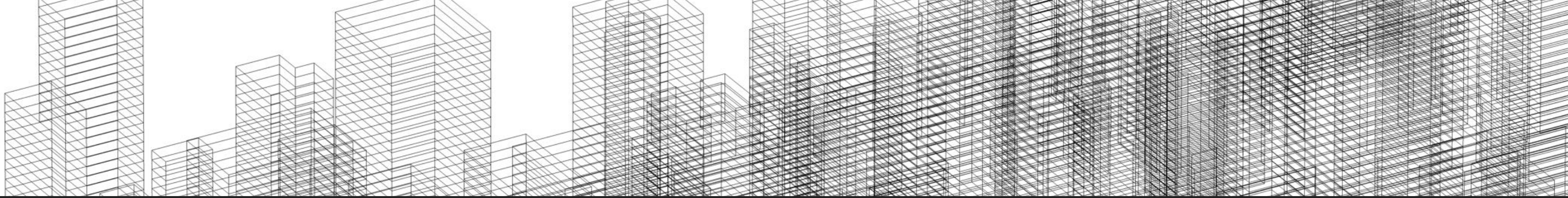
Work Division

- Boya Song : Manager / Tester
  - Integration of the whole project.
  - Implemented the basic structure of codegen.
  - Implementation of matrix inner structure, function, and some built-in functions.
  - Testing

- Chunli Fu: System Architect / Tester
  - Semantic checking for expressions and statements.
  - Testing for semantic checking.

- Mingye Chen: Language Guru / Tester
  - Syntax designing for the language.
  - Scanning and parsing for the program.
  - Testing.

- Yuli Han: System Architect / Tester
  - Implementation of arithmetic expressions and built-in functions.
  - Integration testing.



Demo

Thanks!

MathLight

A lightweight matrix manipulation language

Boya Song (bs3065) Chunli Fu(cf2710)
Mingye Chen (mc4414) Yuli Han(yh2986)