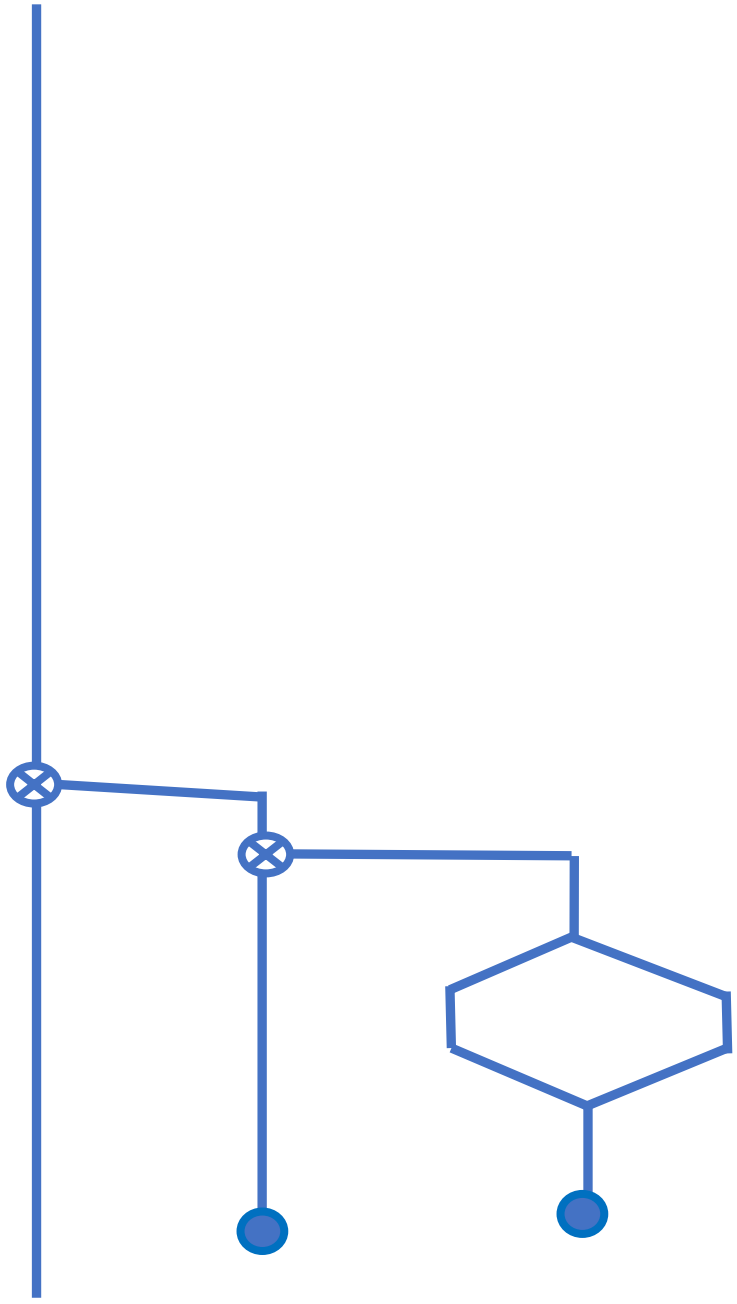

A Two-Dimension Data Structure

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Bill Ragsdale

Forth Data Structures

Forth has a variety of data structures. But they exist for its internal operation.

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Forth's inherent data structures:

Byte/character	_	C@ C!
Word	_ _	W@ W!
Cell	_ _ _ _	@ !
Float	_ _ _ _ _ _ _ _	F@ F!
Array	_ . . . _	specific words
Files		Include, Require

The General Need

Problem oriented data structures are the programmer's responsibility.

Data base
Matrices
Vector graphics
Bit graphics
Sound
Video
AI structures
Simulation structures

My Need

Intended for math and statistical analysis.

Data loaded from .csv files.

Results saved to .csv files.

Data cell size from bytes (1) to floats (8).

Floats and characters for the present.

Notation from *Scientific Forth* by Dr. Julian Noble.

What Can This Structure Do?

Load with literal values
Load with random numbers
Read and write data files.
Formatted print
Math on matrix, row, column, sub-area, cell.
Copy and move by row, column, sub-area, cell.
Multicolumn sort
Linear algebra operations
  Transpose, matrix multiply, equation solution
  Inversion, Gaussian elimination, etc.
Limited alphabetic processing

A Quick Demonstration

```
1 4 create{ x{
x{ {[ 1 2 3 4 ]}
x{ }list
```

```
1.00 2.00 3.00 4.00
```

```
x{ 4 4 }resize
x{ }transpose
x{ }list
```

A Quick Demonstration

```
1 4 create{ x{
x{ {[ 1 2 3 4 ]}
x{ }list
```

```
1.00 2.00 3.00 4.00
```

```
x{ 5 3 }resize
x{ }transpose
x{ }list
```

```
1.00   0.00   0.00
2.00   0.00   0.00
3.00   0.00   0.00
4.00   0.00   0.00
0.00   0.00   0.00
 ok
```

Components

Data area of ‘row x column x cell-size’ bytes.

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A descriptor holding: f (cellsize), R (rows), C (columns) and control pointers.

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A descriptor holding: f (cellsize), R (rows), C (columns) and control pointers.

A Forth name for each matrix.

Words to access matrices, single cells and various row & column combinations.

Conventions

Matrices are referred to by the address of the first byte in their data area.

Descriptors are located by the negative offset from their data area.

Row and column numbers run from 0 .. R-1.

`x{`	matrix names end in `{`
`x{ }name`	`'}'` operates on a full matrix
`x{ r1 c1 }}negate`	`'}}'` operates on one cell.

The Descriptor

Pointer to its name's PFA

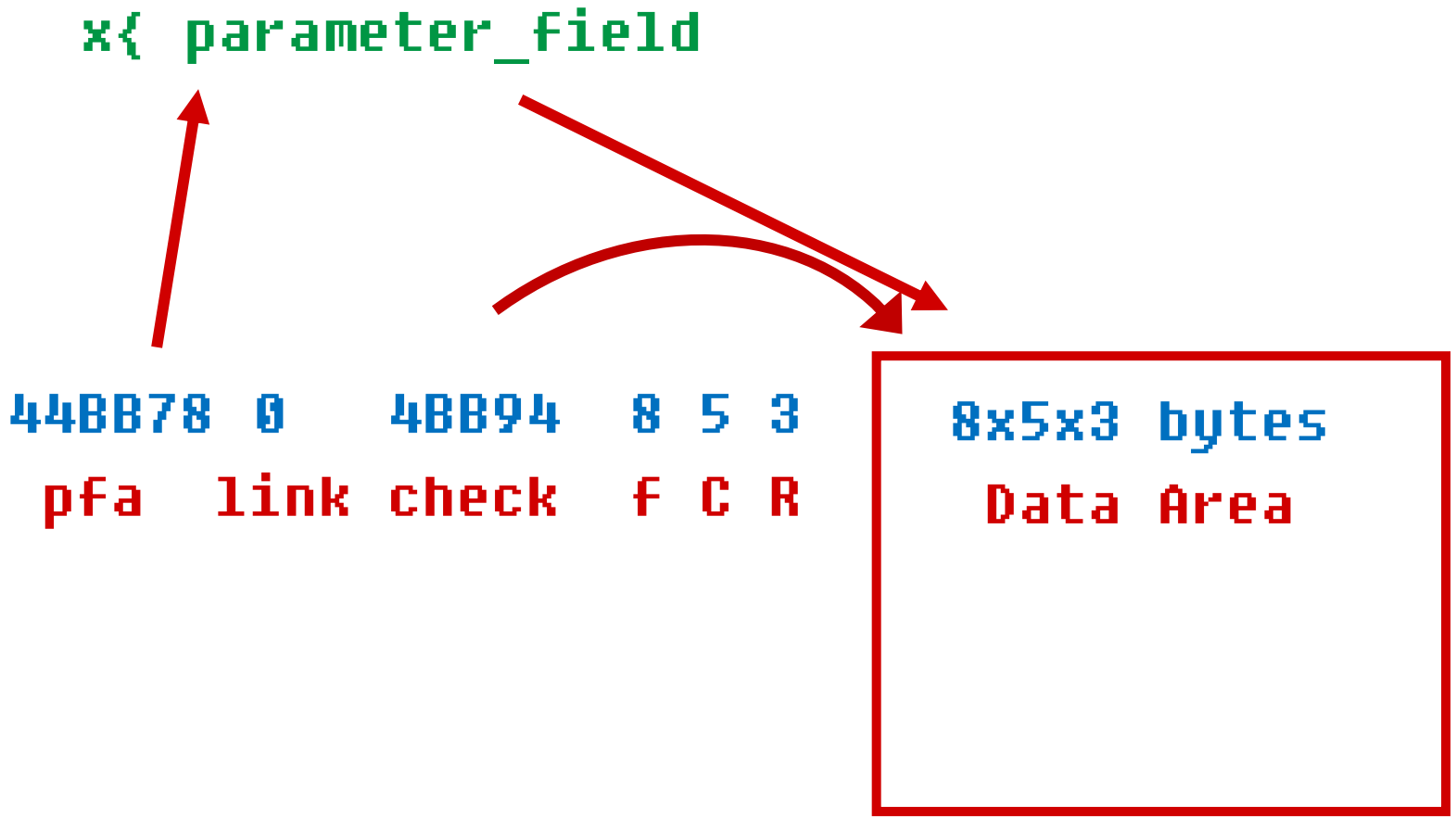
Backlink if resized

Pointer to its data area

Cells size: f (8 bytes for floats)
Number of columns: C
Number of rows: R

```
3 5 create{ x{       x{ }.descriptors

data located at: 44BB94
            pfa: 44BB78  i.e. x{
       backlink: 0
          check: 44BB94
           size: 8
         params: 5 3   ok
```

Shown As In Memory



See The Magic

```
The word doing the ‘heavy lifting’ is: }}

Used as:  x{  r c  }}

Where C is the matrix number of columns,
}} computes
 address+((row * C) + column) * bytes/cell
The initial byte address of a float cell.

: }} ( x{ r1 c1 --- addr )
     swap 2pick }cols   *  +
     over  size: @  *   +  ; Us
```

Access A Cell

```
3 4 create{ x{   x{ }integers  x{ }list

0.0  1.0   2.0   3.0
4.0  5.0   6.0   7.0
8.0  9.0  10.0  11.0

x{ 1 1 }} F@ F.

5.0  ok
```

Row-wise Arithmetic

```
4 3 create{ x{
x{ 1 7e }r#fill
x{ 2 2e }r#fill
x{ 1 x{ 2 x{ 3 }rrr+
x{ }list
```

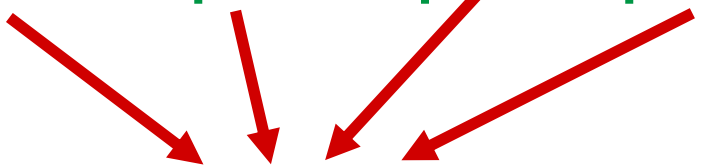
```
0.0  0.0  0.0
7.0  7.0  7.0
2.0  2.0  2.0
9.0  9.0  9.0
 ok
```

Matrix Operators

```
create{  create{*

}list,  }sublist

}copy,  }rcopy, }ccopy, }subcopy

}clear, }integers, }random, }resize

}dimensions, }rows, }cols, }cells, }bytes

}det, }transpose, }invert, }bubble
```

All Math Operators

Matrix	}+	}-	}.*	}./
Common row	}r+	}r-	}r.*	}r./
Independent rows	}rrr+	}rrr-	}rrr.*	}rrr./
Common column	}c+	}c-	}c.*	}c./
Independent columns	}ccc+	}ccc-	}ccc.*	}ccc./
Single cell	}rc+	}rc-	}rc.*	}rc./
Common sub-cell	}com+	}com-	}com.*	}com./
Independent sub-cells	}sub+	}sub-	}sub.*	}sub./



Common root word → ()SubX)

Note: }.* and }./ are cell by cell.

Alphanumerics

```
1 3 15 create{*  alpha{
alpha{  }alphafill
alpha{  }charlist

ABCDEFGHIJKLMNO
PQRSTUVWXYZ[\]^
_`abcdefghijklm  ok
```

Look Within A Definition

```
 0.00  1.00  2.00  3.00  4.00
 5.00  6.00  7.00  8.00  9.00
10.00 11.00 12.00 13.00 14.00

x{ }transpose
```

Look Within A Definition

```
 0.00  1.00  2.00  3.00  4.00
 5.00  6.00  7.00  8.00  9.00
10.00 11.00 12.00 13.00 14.00

x{ }transpose

                      0.00  5.00  10.0
                      1.00  6.00  11.0
                      2.00  7.00  12.0
                      3.00  8.00  13.0
                      4.00  9.00  14.0
                       ok
```

Look Within A Word

```
: }Transpose ( x{ --- )
%{  dup }dimensions opentransient{
dup transient{ }copy
dup params: 2@ swap  2pick params: 2!
dup }dimensions swap
   0 do  dup 0 do
      transient{ i j }}@
            over j i }}!
      loop loop
2drop closetransient{ ;
```

Missing something? Find a model and modify.

Generate Random Data

```
Matrix 16 x 1                16 1 create{ ref{

Fill random integers         ref{ 10e 0e }random

Matrix 16 x 2                16 2 create{ x{

Fill random floats           x{ 100e 1e }random

Copy integers column 0       ref{ x{ 0 }cCopy

List the composite           x{ }list
```

```
0.00   4.3
7.00  69.4
5.00  79.9
2.00   9.6
5.00  41.1
0.00  44.5
0.00  96.2
8.00  77.1
4.00  26.8
1.00  43.4
0.00  88.8
2.00  16.7
3.00  16.7
0.00  57.0
0.00  79.5
9.00  51.4
```

Sort On Column 1 Then Column 0

```
0.00    4.3
7.00   69.4
5.00   79.9
2.00    9.6
5.00   41.1
0.00   44.5
0.00   96.2
8.00   77.1
4.00   26.8
1.00   43.4
0.00   88.8
2.00   16.7
3.00   16.7
0.00   57.0
0.00   79.5
9.00   51.4
```

```
x{ 1 }bubble
x{ 0 }bubble

x{ }list
```

```
0.00    4.6
0.00   44.5
0.00   57.0
0.00   79.5
0.00   88.8
0.00   96.2
1.00   43.4
2.00    9.6
2.00   16.7
3.00   16.7
4.00   26.8
5.00   41.1
5.00   79.9
7.00   69.4
8.00   77.1
9.00   51.4
```

Sort Performance

A bubble sort with comparisons: $(n^2 + n)/2$

```
1000 3  create{ x{   x{ 1000e 0e }random
x{ 0 }bubble
```

```
   100 rows       16 msec.
 1,000 rows      1.9 seconds.
 5,000 rows     31.8 seconds.
10,000 rows    1 min 57 seconds
```

For daily data that covers 27 years.

Benefits

A very flexible data structure.

A rich suite of support words.

Current words easily modified for other needs.

So, see my Win32Forth Guide on Github.

Future Work

Add file support.

Add statistics support.

Possibly, text entries and added number types.

Expand report generation choices.

Credits

- Andrew McKewan and Tom Zimmer for Win32Forth.
- The European team who updated it in the early 2000s.
- Dr. Julian V. Noble, *Scientific Forth*

References

- https://github.com/BillRagsdale/Forth_Projects
- https://github.com/BillRagsdale/WIN32Forth-Guide