Sparse Matrix Research and Software Development at the University of Florida

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with support from NSF, DOE (Sandia)

July 11, 2008

Some background

- PhD, Univ. of Illinois (1989)
- CERFACS postdoc (1989-1990, with Iain Duff)
- Professor, Univ. of Florida (1991 to date)
- sparse matrix software development:
  - UMFPACK: sparse multifrontal LU
  - AMD, COLAMD: ordering methods
  - CHOLMOD: sparse Cholesky, update/downdate
  - KLU: sparse LU for circuit simulation
  - CSparse: a concise sparse matrix package
  - UF Sparse Matrix Collection
  - codes in use in: MATLAB, Mathematica, NASTRAN, Cadence, IBM, Octave, R, ARPACK, Trilinos, Xyce, Debian / Ubuntu Linux, Computational EM Works, deal.II, SciPi, dozens of others

A personal viewpoint

- other examples of robust academic codes: LINPACK, EISPACK, LAPACK, BLAS, FFTW, ARPACK, FDLIB, MINOS, PARDISO, ...
- and codes that once were: MATLAB, CPLEX, ...
- Why should an academic write robust, commercial-quality code?
  - impact
  - software is publishable (ACM TOMS, books, ...)
  - royalty income
  - consulting income

Cultural gap

Goal	Academia	Industry/Govt
new theory, algo, data structures	*	
publishable papers	*	
meets a theoretical need	*	
advances state-of-the-art (theory)	*	
advances state-of-the-art (practice)	*	*
competitive performance	*	*
meets a practical need	*	*
software prototypes	goal	means
usable in production code	specific	general
software robustness		*
software generality		*
well-thought out API		*

Software development philosophies

- comments $>$ code
- well-designed API
- robust error handling
- scaffolding code: use it, test it, post it.
- asserts: executable comments
- Valgrind (or Purify)
- it ain't code until it's documented
- it ain't code unless it's maintained
- 100% statement coverage
- MATLAB as prototype, test engine
  (and end target, depending on the project)

Payoff: reliable, usable code

code	date	# lines main code	# lines test code	bugs affecting MATLAB	total # bugs	bugs/ 1k lines
UMFPACK	1994	41,777	13,237	2	6	0.14
AMD	1996	4,395	685	0	0	0
COLAMD	1998	4,311	1,486	0	1	0.15
LDL	2003	1,157	539	-	0	0
CHOLMOD	2005	47,487	13,542	0	8	0.17
CAMD	2005	4,333	590	-	1	0.23
CCOLAMD	2006	6,481	373	-	0	0
CSparse	2006	2,229	415	0	1	0.45
KLU	2007	10,223	2,059	-	0	0
SF/SSMULT	2007	5,466	693	0	0	0
total		127,859	33,619	2	17	0.13

Payoff: reliable, usable code

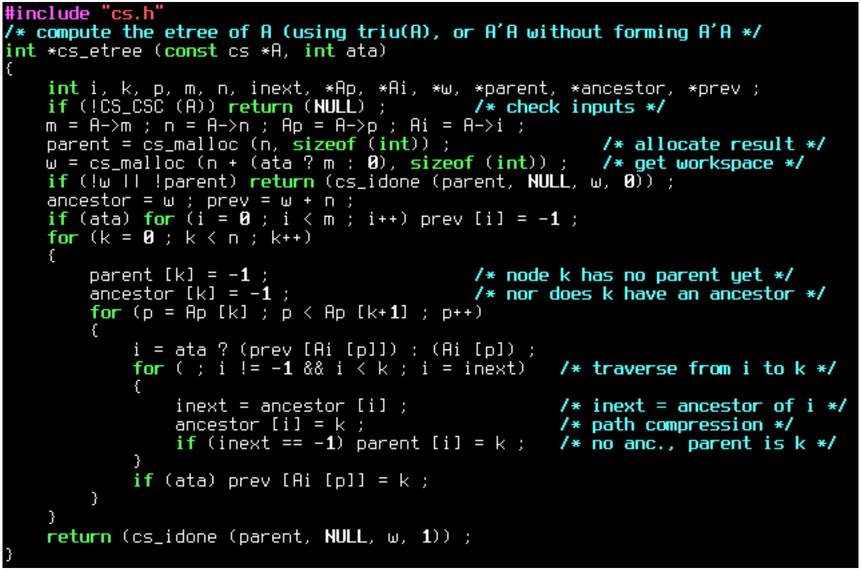
- typical high-quality production code (CMM5): 1 bug/Kloc
- NASA Software Assurance Technology Center:
  - obtained 0.1 bug/Kloc
  - “unachievable for real-world codes”
- UF sparse matrix codes
  - 128K lines total, 17 bugs (0.13 bug/Kloc)
  - 105K lines code in MATLAB, 2 bugs (0.02 bug/Kloc)
  - modest # of code-related publications:
    15 journal articles, 1 book

Licensing

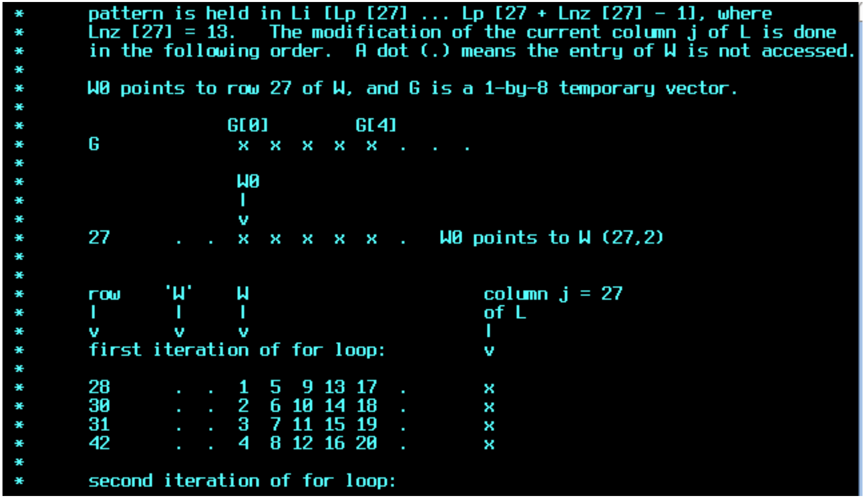
- open-source flavors
  - BSD-like
  - GNU LGPL (“non-viral GNU”)
  - GNU GPL (“viral GNU”)
- dual-source
  - provide both open-source and commercial licenses
  - works well in conjunction with consulting
- closed-source

Software as art

- academic payoff aside: do what you love ...
- software as art
  - beauty of logic
  - beauty of form



```c
#include "cs.h"
/* compute the etree of A (using triu(A), or A'A without forming A'A */
int *cs_etree (const cs *A, int ata)
{
    int i, k, p, m, n, inext, *Ap, *Ai, *w, *parent, *ancestor, *prev ;
    if (!CS_CSC (A)) return (NULL) ;           /* check inputs */
    m = A->m ; n = A->n ; Ap = A->p ; Ai = A->i ;
    parent = cs_malloc (n, sizeof (int)) ;              /* allocate result */
    w = cs_malloc (n + (ata ? m : 0), sizeof (int)) ;   /* get workspace */
    if (!w || !parent) return (cs_idone (parent, NULL, w, 0)) ;
    ancestor = w ; prev = w + n ;
    if (ata) for (i = 0 ; i < m ; i++) prev [i] = -1 ;
    for (k = 0 ; k < n ; k++)
    {
        parent [k] = -1 ;                      /* node k has no parent yet */
        ancestor [k] = -1 ;                    /* nor does k have an ancestor */
        for (p = Ap [k] ; p < Ap [k+1] ; p++)
        {
            i = ata ? (prev [Ai [p]]) : (Ai [p]) ;
            for ( ; i != -1 && i < k ; i = inext)   /* traverse from i to k */
            {
                inext = ancestor [i] ;              /* inext = ancestor of i */
                ancestor [i] = k ;                  /* path compression */
                if (inext == -1) parent [i] = k ;   /* no anc., parent is k */
            }
            if (ata) prev [Ai [p]] = k ;
        }
    }
    return (cs_idone (parent, NULL, w, 1)) ;
}
```



```
*       pattern is held in Li [Lp [27] ... Lp [27 + Lnz [27] - 1], where
*       Lnz [27] = 13.    The modification of the current column j of L is done
*       in the following order.  A dot (.) means the entry of W is not accessed.
*
*       W0 points to row 27 of W, and G is a 1-by-8 temporary vector.
*
*                    G[0]        G[4]
*       G             x   x   x   x   x   .   .   .
*
*                     W0
*                     |
*                     v
*       27        .   .   x   x   x   x   x   .   W0 points to W (27,2)
*
*
*       row     'W'     W                           column j = 27
*       |        |      |                           of L
*       v        v      v                           |
*       first iteration of for loop:                v
*
*       28        .   .   1   5   9  13  17   .     x
*       30        .   .   2   6  10  14  18   .     x
*       31        .   .   3   7  11  15  19   .     x
*       42        .   .   4   8  12  16  20   .     x
*
*       second iteration of for loop:
```

Software as poetry

Software as poetry

Sea Fever, by Masefield (1902)

I must go down to the seas again, to the lonely sea and the sky,
And all I ask is a tall ship and a star to steer her by,
And the wheel's kick and the wind's song
    and the white sail's shaking,
And a grey mist on the sea's face and a grey dawn breaking.

Software as poetry

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C Fever, by T.D. (2008)

I must go code in the C again, to the lonely C and VI,
And all I ask is a Linux box and a mouse to steer her by,
And the while's break and the if-then
    and the valgrind's shaking,
And a dash O so the C's fast and a switch case breaking.

Software as poetry

Sea Fever

I must go down to the seas again, for the call of the running tide
Is a wild call and a clear call that may not be denied;
And all I ask is a windy day with the white clouds flying,
And the flung spray and the blown spume, and the sea-gulls crying.

Software as poetry

Sea Fever

I must go down to the seas again, for the call of the running tide
Is a wild call and a clear call that may not be denied;
And all I ask is a windy day with the white clouds flying,
And the flung spray and the blown spume, and the sea-gulls crying.

C Fever

I must go code in the C again, for the call of recursive code
Is a wild call and a clear call that runs and won't be slowed;
And all I ask is a tall latte with the white foam frothing,
And no flung err and no blown stack, and the C goes flying.

Software as poetry

Sea Fever

I must go down to the seas again, to the vagrant gypsy life,
To the gull's way and the whale's way
where the wind's like a whetted knife;
And all I ask is a merry yarn from a laughing fellow-rover,
And quiet sleep and a sweet dream when the long trick's over.

Software as poetry

Sea Fever

I must go down to the seas again, to the vagrant gypsy life,
To the gull's way and the whale's way
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C Fever

I must go code in the C again, to the lonely code frontier,
Where no goto's in the while's way,
        where the logic is sharp and clear;
And all I ask is a #define from a fellow C-programmer,
And quiet sleep when a clean doc's in the LaTeX grammar.

Summary

- Robust software development very compatiable with an academic career
- Academic / Industrial cultural gap can be bridged
- Good code is a useful research result
- Dual-source (multi-licensing):
  - open-source (GNU), with commercial licenses available
  - allows for wide use
  - allows for licensing and consulting income