Generic Code Optimization

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ICL UT
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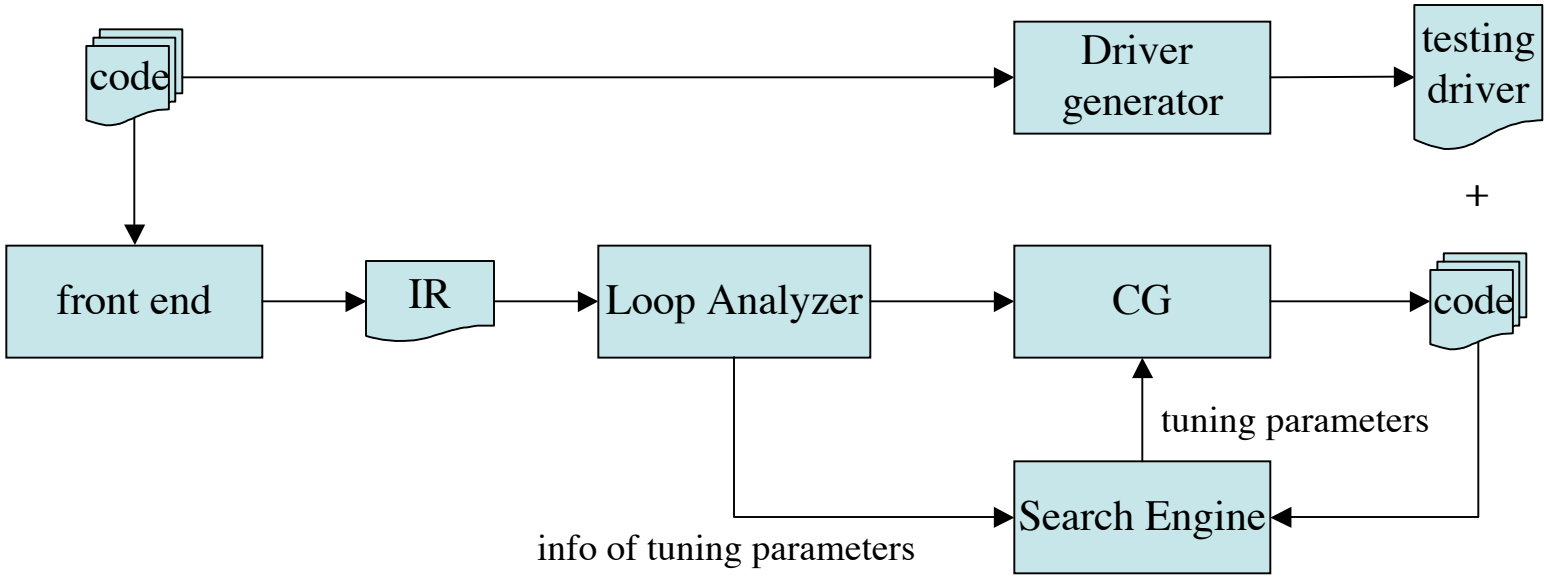
Generic Code Optimization

- Take generic code segments and perform optimizations via experiments (similar to ATLAS)
- Collaboration with ROSE project (source-to-source code transformation / optimization) at Lawrence Livermore National Laboratory
  - Daniel Quinlan and Qing Yi

GCO

- A source-to-source transformation approach to optimize arbitrary code, especially loop nests in the code.
  - Machine parameters detection
  - Source to source code generation
  - Testing driver generation
  - Empirical search engine

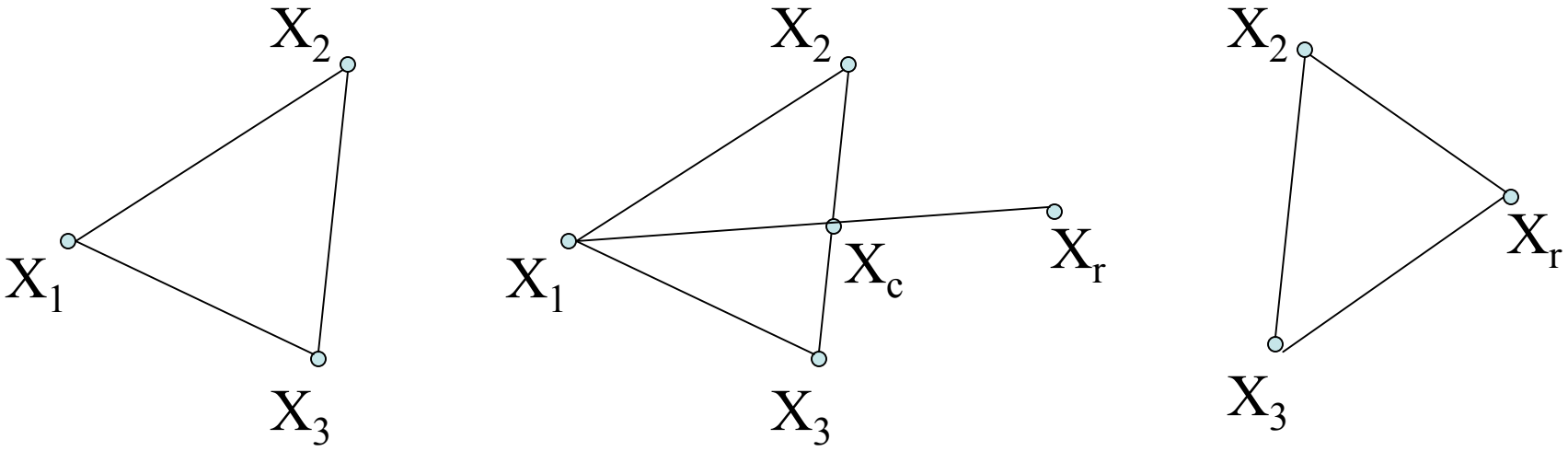
GCO Framework



Simplex Method

- Simplex method is a non-derivative direct search method for optimal value
- N+1 points of N dimension search space make up a simplex
- Basic Operations: reflection, expansion, contraction, and shrink.

Basic Simplex



Basic idea of Simplex Method in 2D:

- To find maximum value of f(x) in a 2-dim search space
- The simplex consists X_1, X_2, X_3. suppose $f(X_1) <= f(X_2) <= f(X_3)$
- In each step, we can find X_c which is the centroid of X_2 and X_3, replace X_1 with X_r which is the reflection of X_1 through X_c.

DGEMM ATLAS Search Space

8 dimensional space for search

ATLAS does orthogonal searching

Represents 1 M search points!!

NB: Cache Blocking

LAT: FP unit latency

MU NU: Register Blocking

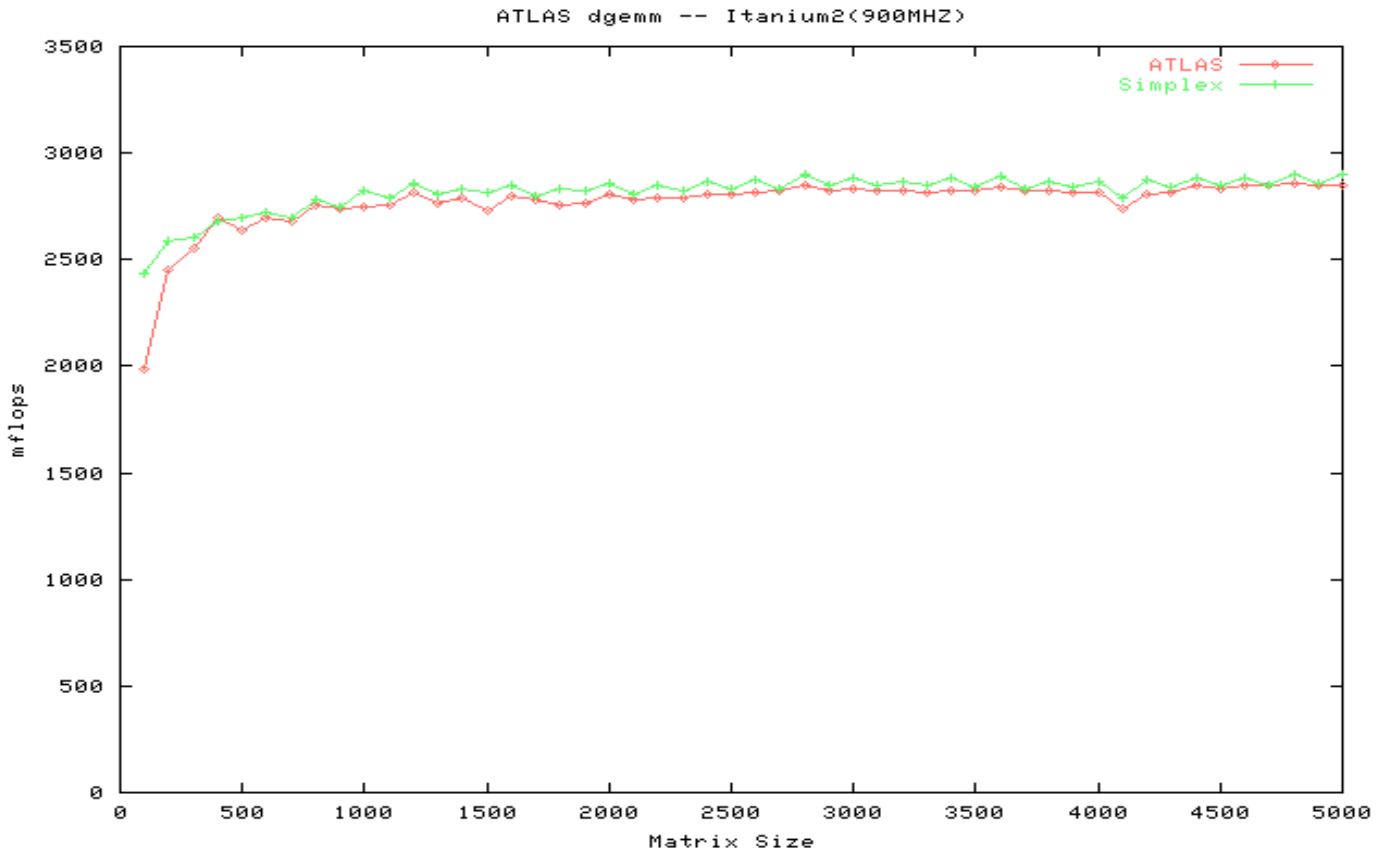
KU: unrolling

FFTCH: determine prefetch of matrix C into registers

IFTCH NFTCH: determine the interleaving of loads with computation

simplex32	LAT	NB	MU	NU	KU	FFTCH	IFTCH	NFTCH
upper bound	16	32	16	16	32	1	16	16
lower bound	1	16	1	1	1	0	2	1

Comparison of performance of DGEMM generated with ATLAS and Simplex search



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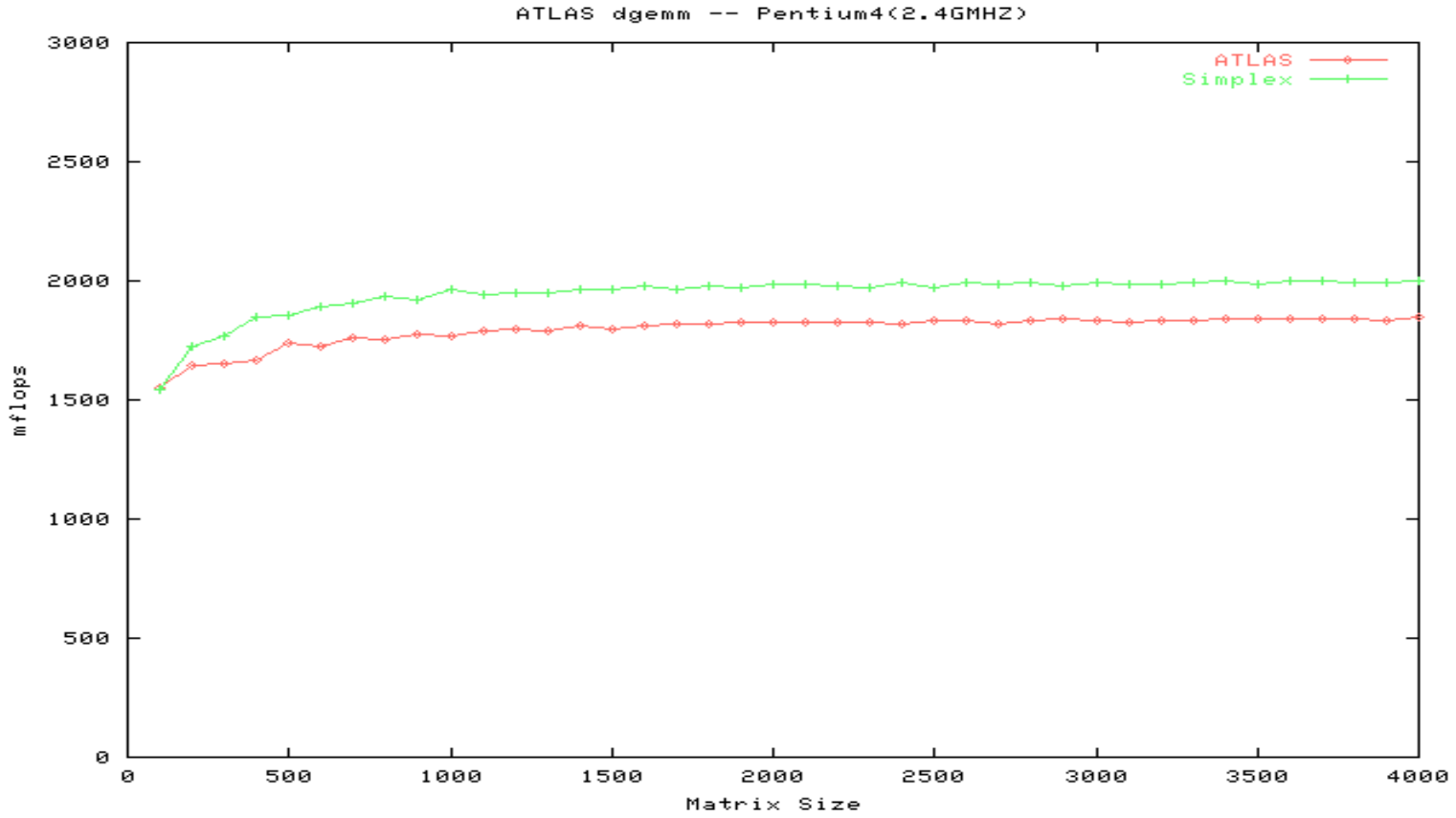

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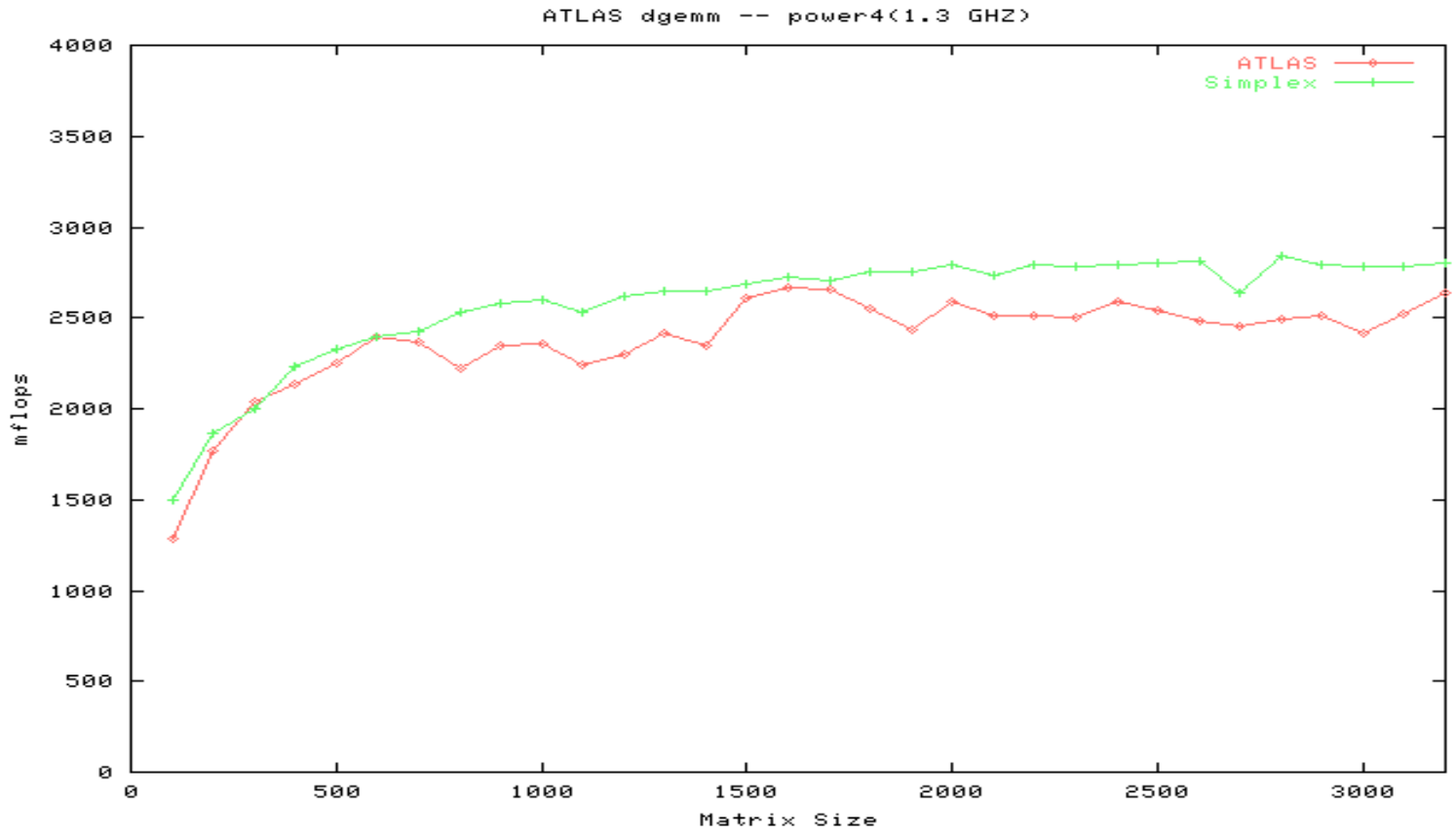

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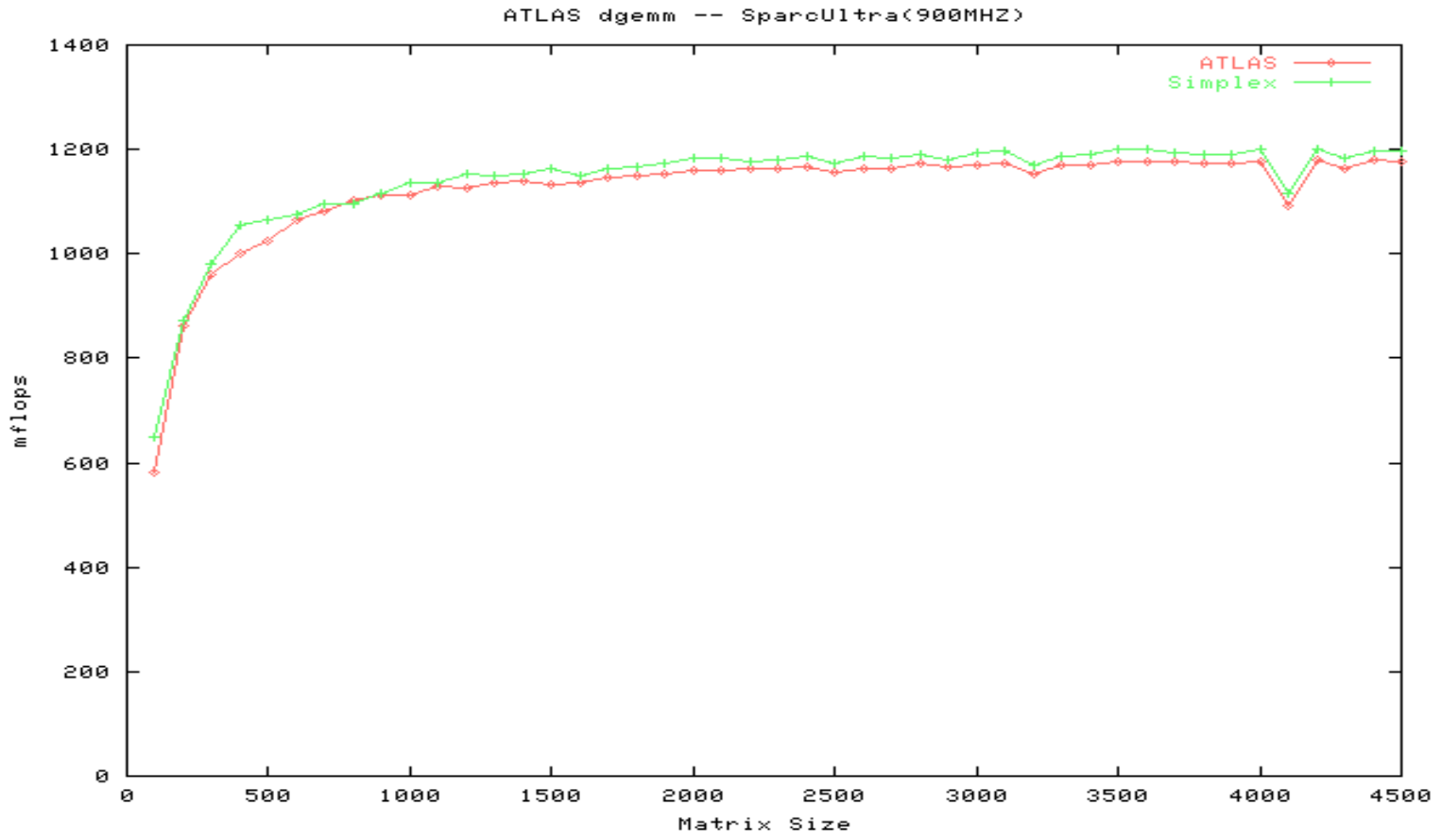
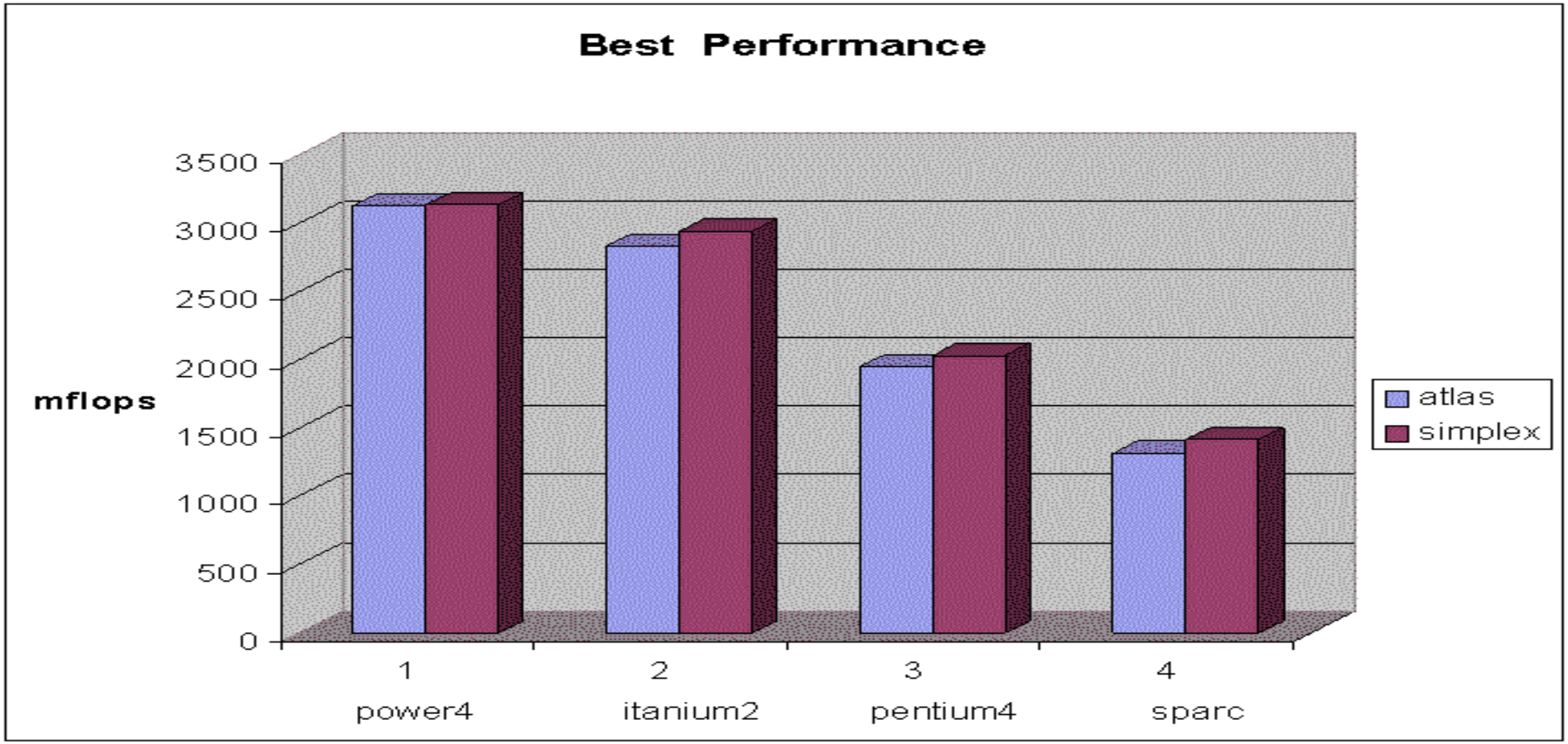
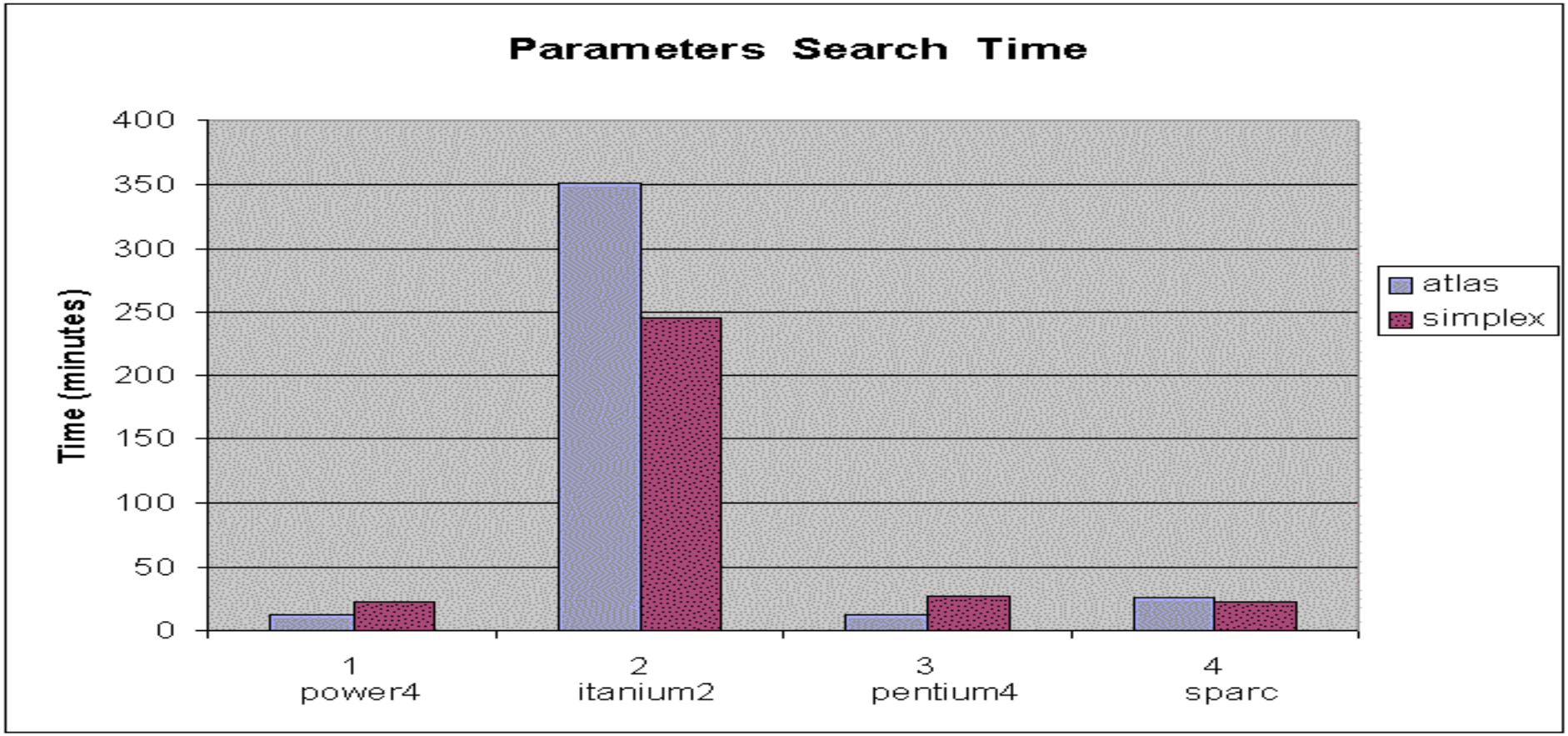


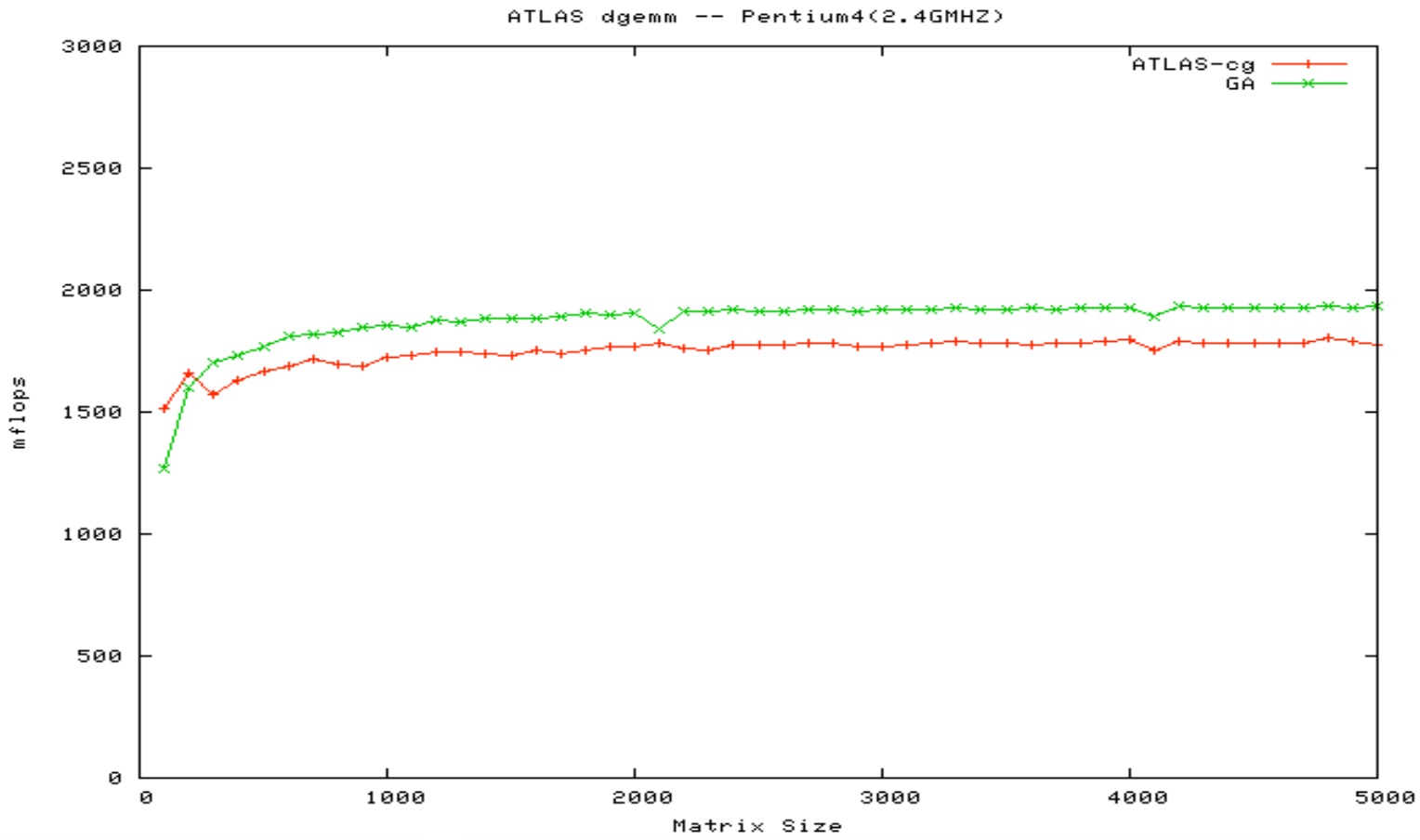
Comparison of performance of DGEMM on1000x1000 matrix generated with ATLAS and Simplex search



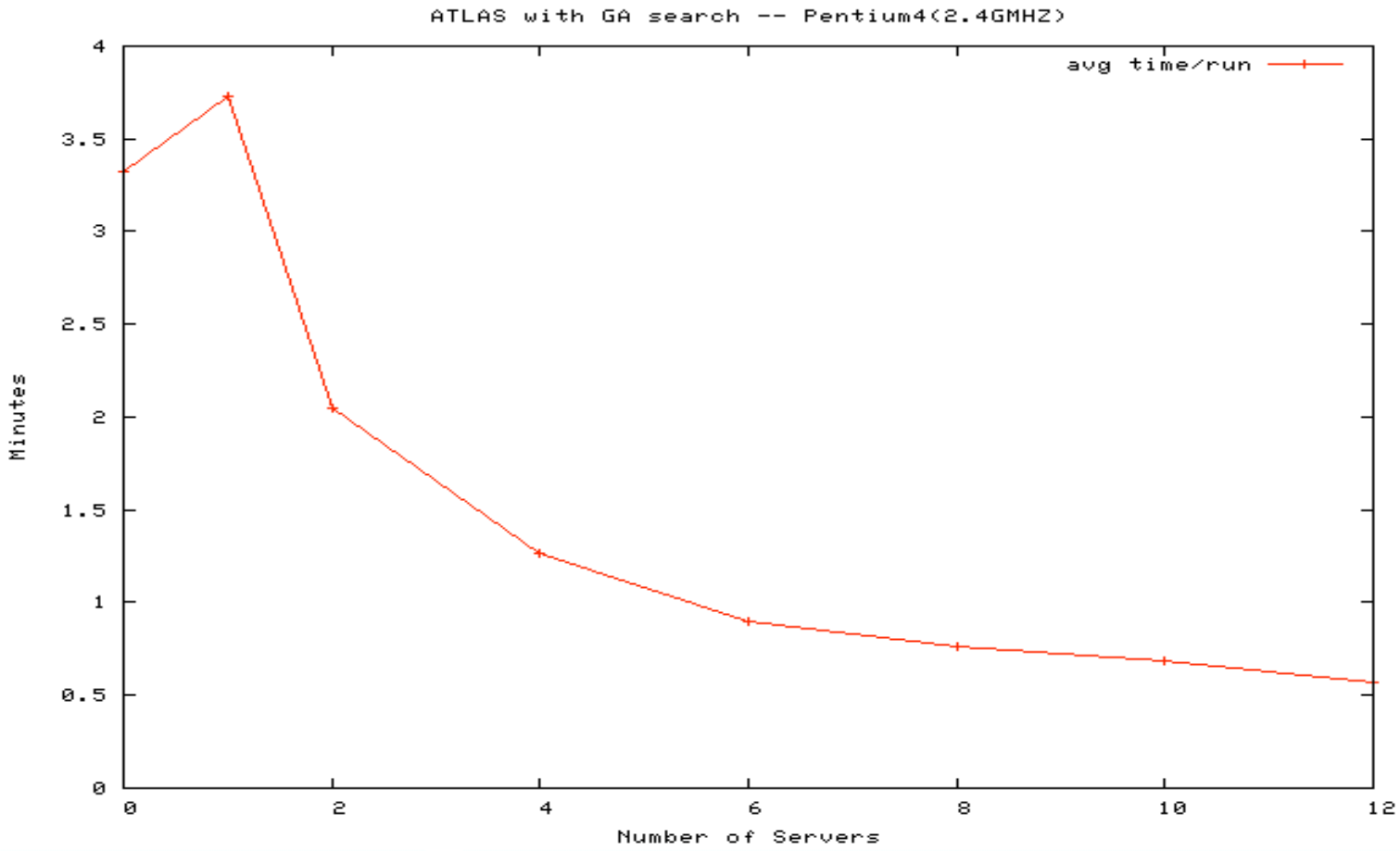
Comparison of parameters' search time ATLAS and Simplex search



Comparison of performance of DGEMM generated with ATLAS and Parallel GA(GridSolve)



Comparison of parameters' search time ATLAS and Parallel GA(GridSolve)



Code Generation

- Collaboration with ROSE project (source-to-source code transformation/optimization) at Lawrence Livermore National Laboratory
- LoopProcessor -bk3 4 -unroll 4 ./dgemv.c

Testing Driver Generation

```
/*$ATLAS ROUTINE DGEMV */
/*$ATLAS SIZE 1000:2000:100 */
/*$ATLAS ARG M          IN     int     $size */
/*$ATLAS ARG N          IN     int     $size */
/*$ATLAS ARG ALPHA      IN     double  1.0 */
/*$ATLAS ARG A[M][N]    IN     double  $rand */
/*$ATLAS ARG B[N]       IN     double  $rand */
/*$ATLAS ARG C[M]       INOUT  double  $rand */

void dgemv (int M, int N, double alpha, double* A, double * B,
double* C)
{
  int i, j;

    /* matrices are stored in column major */
    for (i = 0; i < M; ++i) {
      for (j = 0; j <N ; ++j) {
        C[i] += alpha * A[j*M + i] * B[j];
      }
    }
}
```

- Testing driver initializes variables and collects performance data.
- Wallclock time or Hardware counter data

```
/*$ATLAS ROUTINE DGEMV */
/*$ATLAS SIZE 1000:1000:1 */
/*$ATLAS ARG M          IN     int     $size */
/*$ATLAS ARG N          IN     int     $size */
/*$ATLAS ARG ALPHA      IN     double  1.0 */
/*$ATLAS ARG A[M][N]    IN     double  $rand */
/*$ATLAS ARG B[N]       IN     double  $rand */
/*$ATLAS ARG C[M]       INOUT  double  $rand */


void dgemv (int M, int N, double alpha, double* A, double * B,
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{
 int i, j;


   /* matrices are stored in column major */
   for (i = 0; i < M; ++i) {
    for (j = 0; j <N ; ++j) {
     C[i] += alpha * A[j*M + i] * B[j];
    }
   }
}
```
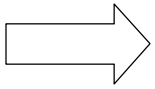
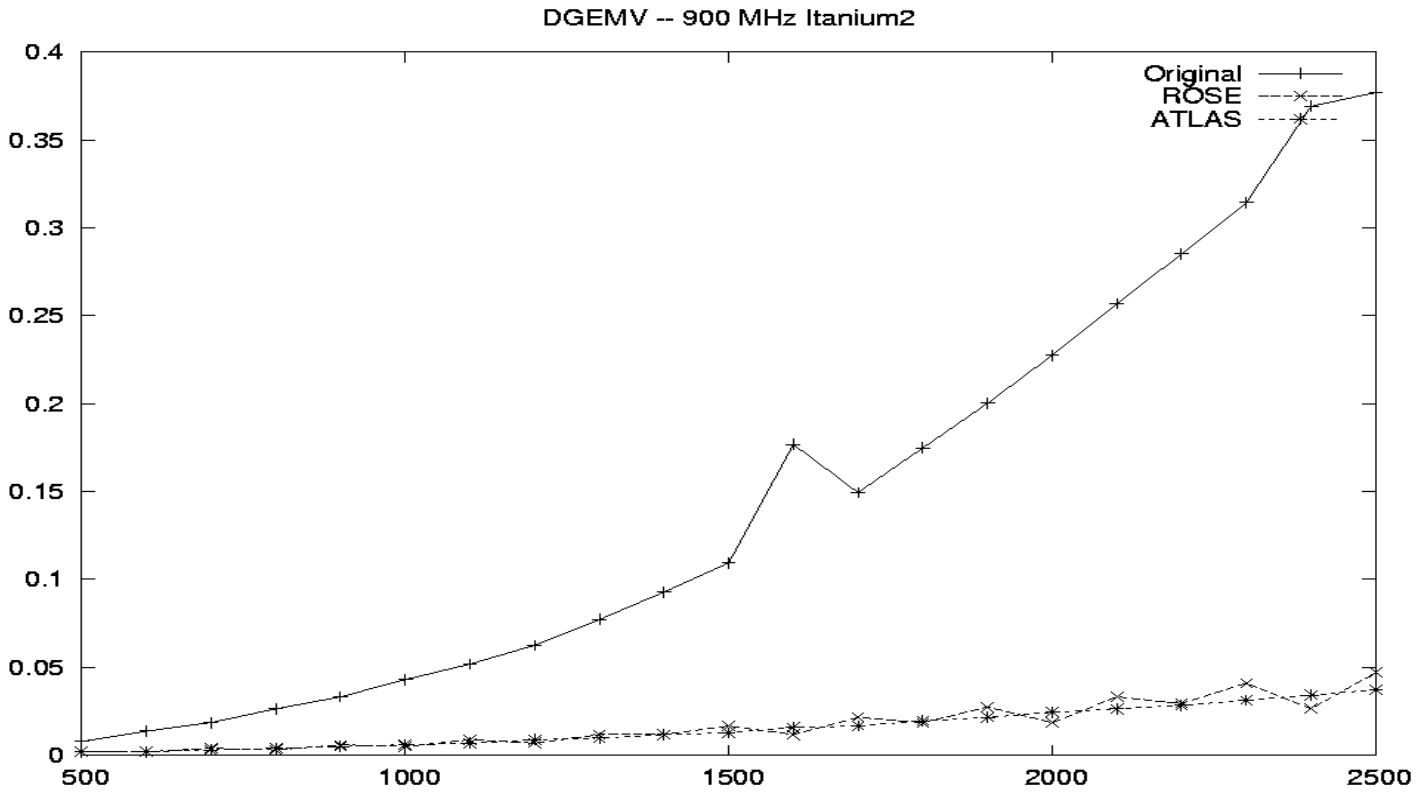
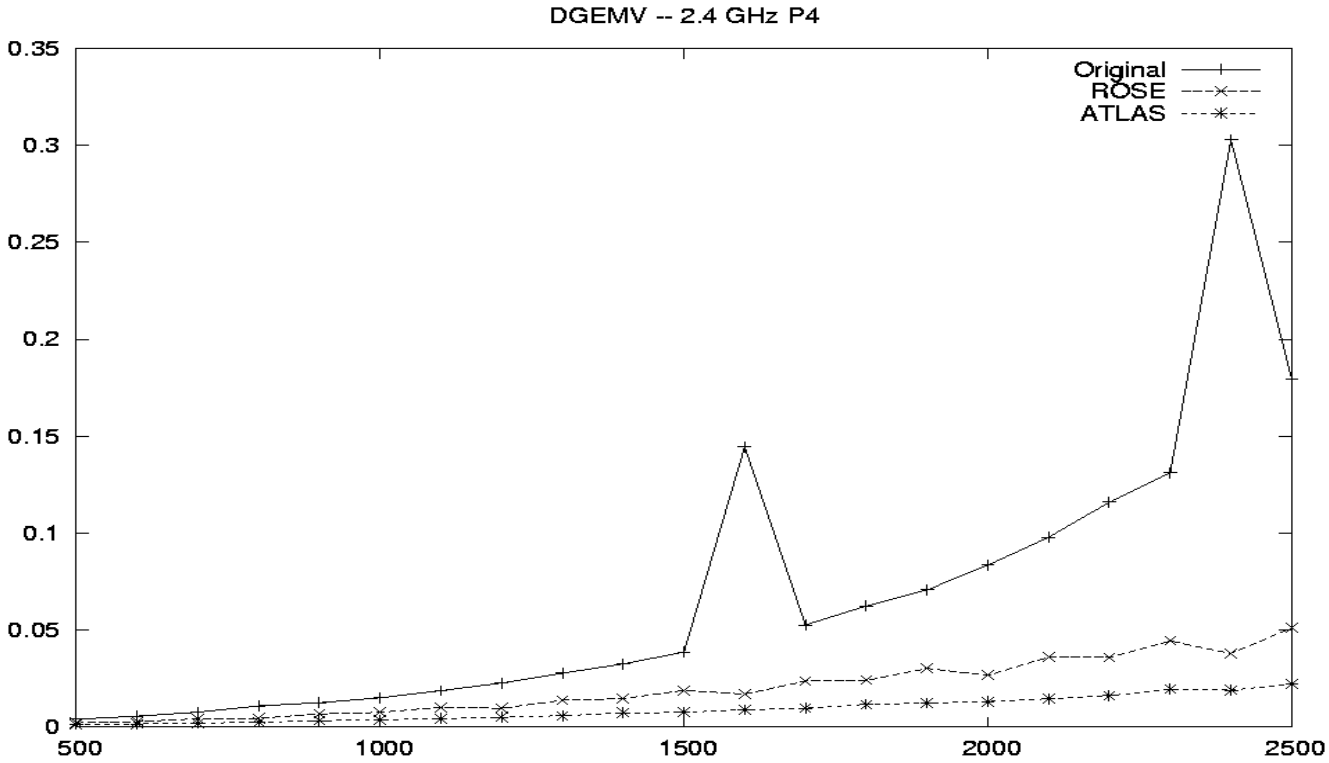



```
int min(int ,int );
/*$ATLAS ROUTINE DGEMV */
/*$ATLAS SIZE 1000:1000:1 */
/*$ATLAS ARG M          IN     int     $size */
/*$ATLAS ARG N          IN     int     $size */
/*$ATLAS ARG ALPHA      IN     double  1.0 */
/*$ATLAS ARG A[M][N]    IN     double  $rand */
/*$ATLAS ARG B[N]       IN     double  $rand */
/*$ATLAS ARG C[M]       INOUT  double  $rand */


void dgemv(int M,int N,double alpha,double * A,double * B,double * C)
{
 int _var_1;
 int _var_0;
 int i;
 int j;
 for (_var_1 = 0; _var_1 <= -1 + M; _var_1 += 4) {
  for (_var_0 = 0; _var_0 <= -1 + N; _var_0 += 4) {
   for (i = _var_1; i <= min((-1 + M),(_var_1 + 3)); i += 1) {
    for (j = _var_0; j <= min((N + -4),_var_0); j += 4) {
     C[i] += (alpha * A[(j * M + i)]) * B[j];
     C[i] += (alpha * A[((1 + j) * M + i)]) * B[(1 + j)];
     C[i] += (alpha * A[((2 + j) * M + i)]) * B[(2 + j)];
     C[i] += (alpha * A[((3 + j) * M + i)]) * B[(3 + j)];
    }
    for (; j <= min((-1 + N),(_var_0 + 3)); j += 1) {
     C[i] += (alpha * A[(j * M + i)]) * B[j];
    }
   }
  }
 }
}
```

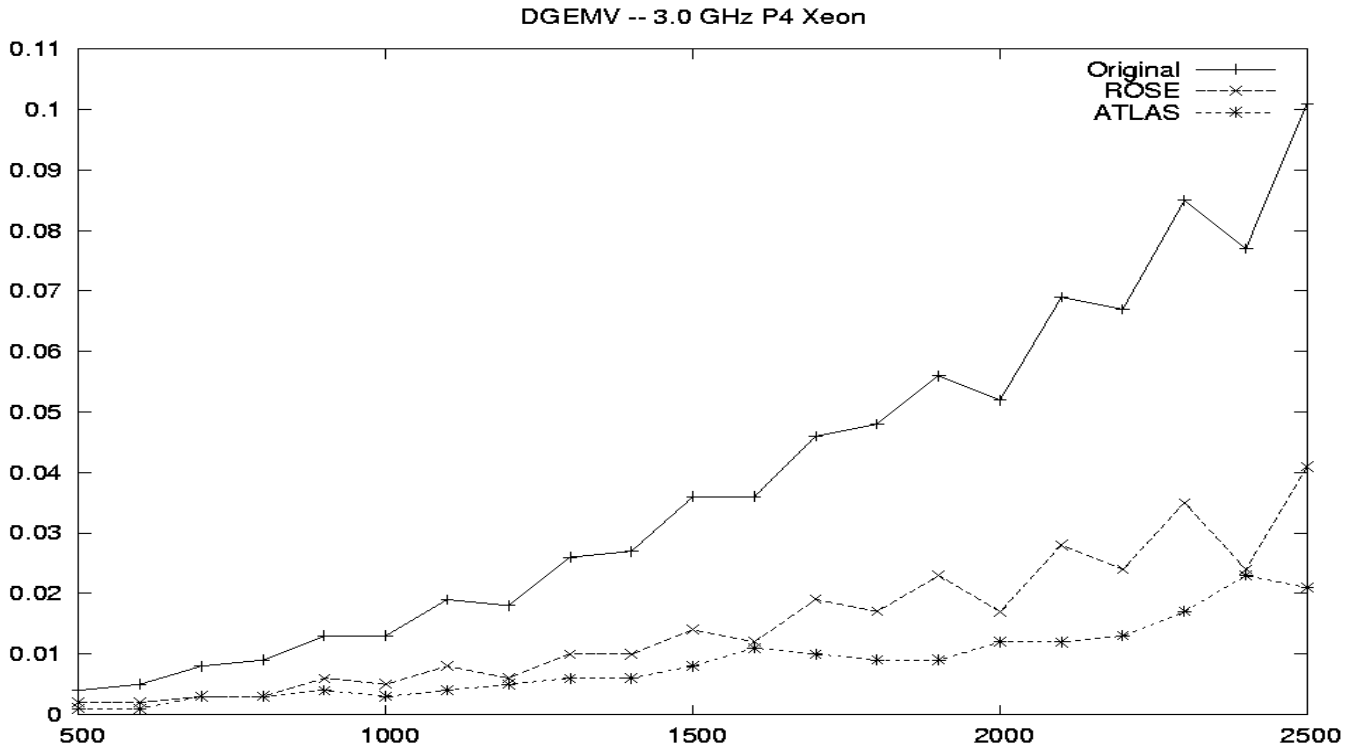
Comparison of performance of DGEMV generated with ATLAS and Simplex search with ROSE



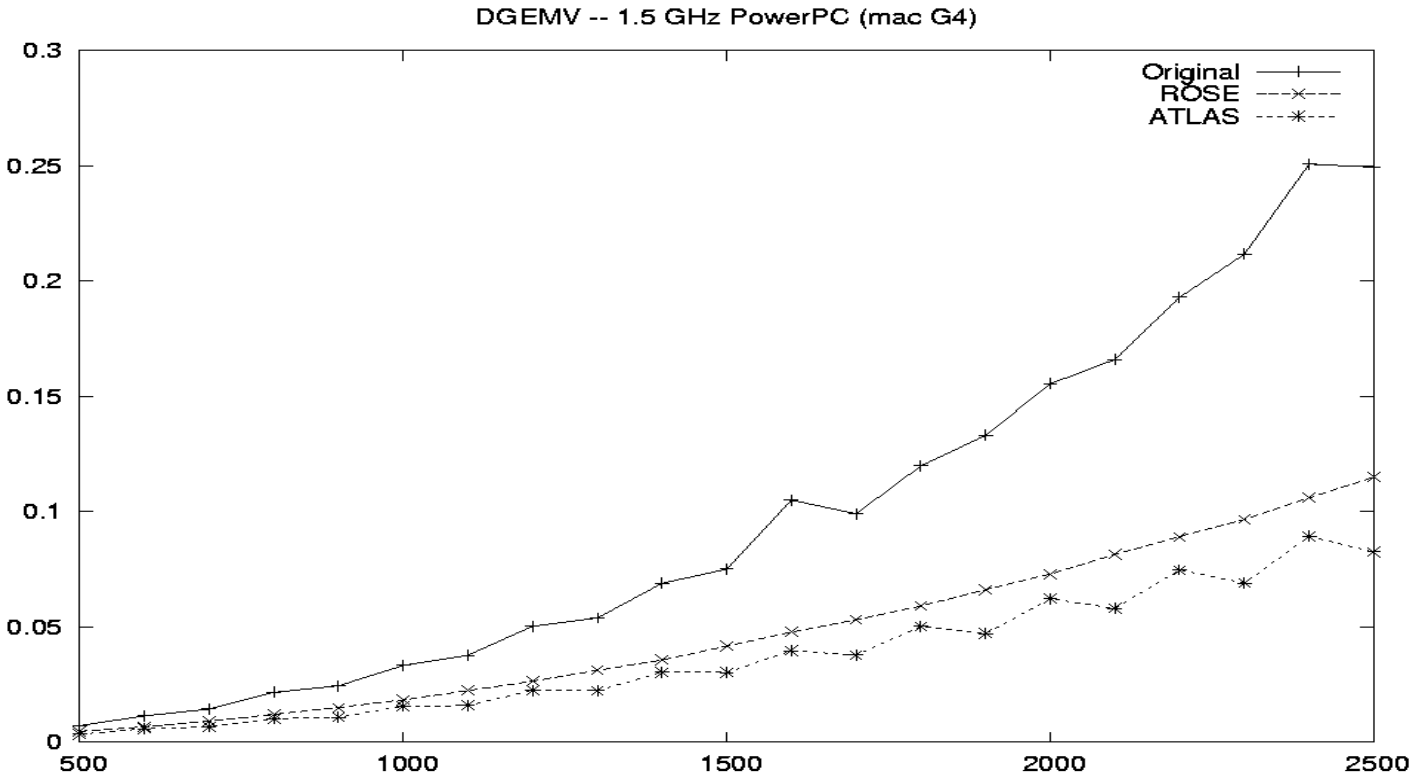
Comparison of performance of DGEMV generated with ATLAS and Simplex search with ROSE



Comparison of performance of DGEMV generated with ATLAS and Simplex search with ROSE



Comparison of performance of DGEMV generated with ATLAS and Simplex search with ROSE



```
void dgemv(int M,int N,double alpha,double * A,double * B,double * C)
{
  int _var_1;
  int _var_0;
  int i;
  int j;
  int ub1, ub2;

  for (_var_1 = 0; _var_1 <= -1 + M; _var_1 += 113) {
    ub1 = rosemin((-8 + M),(_var_1 + 105));
    for (_var_0 = 0; _var_0 <= -1 + N; _var_0 += 113) {
      ub2 = rosemin((N + -6),(_var_0 + 107));
      for (i = _var_1; i <= ub1; i += 8) {
        for (j = _var_0; j <= ub2; j += 6) {
          register double bjp0, bjp1, bjp2, bjp3, bjp4, bjp5;
          register double cip0, cip1, cip2, cip3, cip4, cip5, cip6, cip7;
          register int t0, t1, t2, t3, t4, t5;

          t0 = j * M + i;
          t1 = (1 + j) * M + i;
          t2 = (2 + j) * M + i;
          t3 = (3 + j) * M + i;
          t4 = (4 + j) * M + i;
          t5 = (5 + j) * M + i;
          cip0 = C[i];
          cip1 = C[i + 1];

          cip2 = C[i + 2];
          cip3 = C[i + 3];
          cip4 = C[i + 4];
          cip5 = C[i + 5];
          cip6 = C[i + 6];
          cip7 = C[i + 7];
          bjp0 = B[j];
          bjp1 = B[j+1];
          bjp2 = B[j+2];
          bjp3 = B[j+3];
          bjp4 = B[j+4];
          bjp5 = B[j+5];
          cip0 += (A[t0]) * bjp0;
          ……..
          C[i+6] = cip6;
          C[i+7] = cip7;
        }
        for (; j <= rosemin(N-1,_var_0+112); j++) {
          C[i] += (alpha * A[j * M + i]) * B[j];
          C[i+1] += (alpha * A[j * M + i+1]) * B[j];
          …….
          C[i+7] += (alpha * A[j * M + i+7]) * B[j];
        }     }
      for (; i <= rosemin((M-1),(_var_1 + 112)); i++) {
        for (j = _var_0; j <= rosemin((N + -1),(_var_0 + 112)); j++) {
          C[i] += (alpha * A[(j * M + i)]) * B[j];
        } }   } } }
```