Towards a matrix-oriented strided interface in OpenSHMEM

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Hanlon’s Razor.
Types of regular/direct data

- Contiguous
- Element Strided
- Block Strided
- Indexed
Data types in APIs

- **Contiguous** - MPI, SHMEM, ARMCI, etc.
- **Element Strided** - MPI, SHMEM, ARMCI, etc.
- **Block Strided** - MPI, SHMEM, ARMCI, etc.
- **Indexed** - MPI, SHMEM, ARMCI, etc.

Where does it make sense to stop?

Why does SHMEM have element strided?
Hardware considerations

- **Contiguous** - Obvious.
- **Element Strided** - Sub-packet elements bad.
- **Block Strided** - Amortize call overhead.
- **Indexed** - Where to stop with descriptors?

If SHMEM message-rate is high enough, all we need to do is exceed packet size.

Except we have to wait on local completion for every call...
Nonblocking SHMEM Put and Get would seriously improve the situation, but one still has $O(N_{\text{MIN}(\text{rows}, \text{cols})})$ function calls for a submatrix.

Some networks (e.g. Cray Aries) don’t let us inject an arbitrary number of nonblocking operations without a synchronization call.

Linear algebra entails a particular data semantic that deserves first-class treatment in the API.

Runtime systems can do more with more...
Global Arrays - (sub)matrices are first-class objects

GA_Put({x,y}, {x',y'})

→ ARMCI_PutS(rank, addr, ...)

 Diagram showing the mapping between Global Arrays and ARMCI_PUTS function.
Submatrix communication

- Algorithmic block size may not match data block size.
- Data access pattern may change over the lifetime of object.
- If embedding complex data in a matrix, may want only one component.
ScaLAPACK block cyclic

A $3 \times 3$ matrix partitioned in $2 \times 2$ blocks

$2 \times 2$ process grid point of view
Submatrix as many contiguous chunks

- Map subarray to vector of contiguous vectors.
- $O(N_{\text{rows}})$ function calls.
- Block until buffer accessible → bad for Get.
- This method far more reasonable with nonblocking.
- Efficient for $N_{\text{cols}} > N_{\text{rows}}$. 
Submatrix as many strided vectors

- Map subarray to vector of strided vectors.
- $O(N_{cols})$ function calls.
- Blocking bad here too.
- Strided touches same cache line repeatedly.
- Efficient for $N_{cols} < N_{rows}$?
Submatrix communication

- One blocking function call.
- Runtime knows everything about data transfer.
- Maps directly to dense linear algebra semantics.
void shmemx_double_apyut(double * dest, const double * src,  
    ptrdiff_t dstr, ptrdiff_t sstr,  
    size_t blksz, size_t blkct, int pe)  
{
    double      *dtmp = dest;  
    const double *stmp = src;  
    if (blksz<blkct) /* may require tuning */ {
        for (size_t i=0; i<blksz; i++) {
            shmem_double_iput(dtmp, stmp, dstr, sstr, blkct, pe);  
            dtmp++; stmp++;  
        }
    } else {
        for (size_t i=0; i<blkct; i++) {
            shmem_double_put(dtmp, stmp, blksz, pe);  
            dtmp += dstr; stmp += sstr;  
        }
    }
}
void shmemx_double_aput(double * dest, const double * src,
   ptrdiff_t dstr, ptrdiff_t sstr,
   size_t blksz, size_t blkct, int pe)
{
    int maxnbi = DMAPP_DEF_OUTSTANDING_NONBLOCKING/2;
    double *dtmp = dest;
    const double *stmp = src;
    /* skipping iput implementation */
    for (size_t i=0; i<blkct; i++) {
        dmapp_put_nbi(dtmp, _sheap, pe, (double*)stmp,
           blksz, DMAPP_QW);
        if (i && i%maxnbi==0) dmapp_gsync_wait();
        dtmp += dstr; stmp += sstr;
    }
    if (blkct%maxnbi!=0) dmapp_gsync_wait();
}
Sreeram Potluri and I wrote a highly optimized implementation for IBM® Blue Gene/P® in DCMF® that packed up to packet granularity (active-message unpacking) and otherwise injected directly.

PAMI* (Blue Gene/Q®, PERCS*) has a datatype engine that can in theory map to network DMA scatter-gather.

Surely there is something for InfiniBand®...

OSHMPI (MPI-3 RMA as conduit) maps directly to subarray type.

Any one-sided API that has nonblocking should benefit.

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Performance Results

- The performance improvement over a straightforward implementation on Blue Gene/P was huge. We never compared against SHMEM-like implementation and the hardware is all scrap now 😞
- Cray® XC30 tests at small scale show modest improvement. For small jobs (especially within an Aries quartet) without any contention, the benefit of nonblocking is not too large.

It will be a lot easier to gather performance data by mapping ARMCI to OpenSHMEM since we already have all the performance benchmarks oriented at Global Arrays usage.
Acknowledgements

Jim Dinan (Intel) for an uncountable number of discussions of one-sided in SHMEM, ARMCI...

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