Efficient *Matrix Multiplications* on RISC-V MCUs

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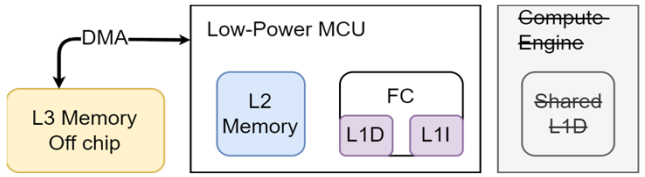
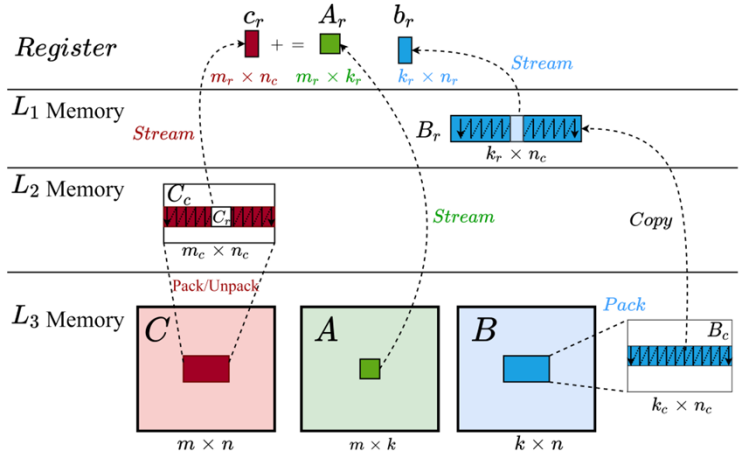
- GAP8
- Leverage Dot product **vector instructions**
- New Multi-level **memory hierarchy**
- Approximate Computing
- Modified BLIS (BLAS-like Library Instantiation Software)

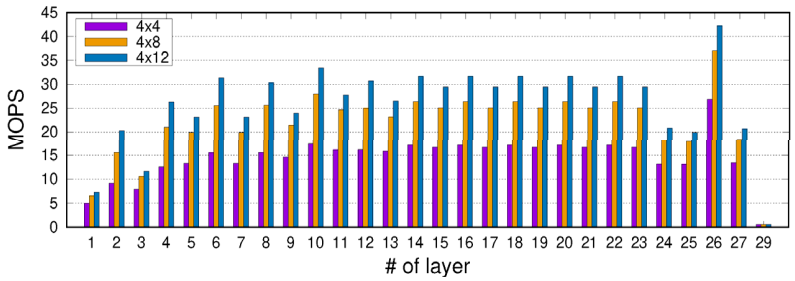
GAP8 **Memory** Architecture



Matrix Packing, Copying, Streaming



Performance on Different **Dimension of Microkernel** and **Convolutional Layers of MobileNet V1**



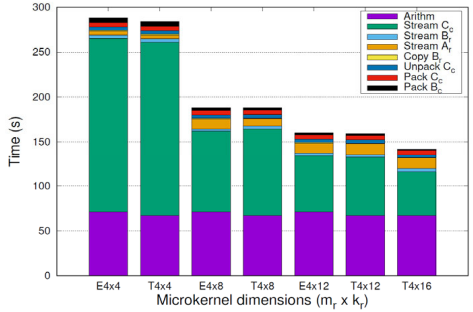
Proposed GEMM algorithm (B3C2A0)

```
L1   for ( jc = 0; jc < n; jc += nc )
L2     for ( pc = 0; pc < k; pc += kc ) {
         Bc ← B(pc : pc + kc − 1, jc : jc + nc − 1); // Pack
L3       for ( ic = 0; ic < m; ic += mc ) {
           Cc ← C(ic : ic + mc − 1, jc : jc + nc − 1); // Pack
L4         for ( pr = 0; pr < kc; pr += kr )
L5           for ( ir = 0; ir < mc; ir += mr )
L6             for ( jr = 0; jr < nc; jr += 1 ) // Micro-kernel
                 Cc(ir : ir + mr − 1, jr)
                   += Ac(ir : ir + mr − 1, pr : pr + kr − 1)
                    · Bc(pr : pr + kr − 1, jr);
           C(ic : ic + mc − 1, jc : jc + nc − 1) ← Cc; // Unpack
       }}
```

Proposed micro-Kernel (Loop 6)

```
gemm_ukernel_ABresident_gap8( int nc, signed char *A, int ldA,
                              signed char Br , signed char Cc )
{
 int jr, baseCB = 0;
 v4s A0, A1, A2, A3, // Columns of the 4x4 micro-tile Ar
     br, cr;         // Columns of Br, Cr

 // Load the columns of the 4x4 micro-tile Ar into vector
registers
 // Simulated in software using the v4s datatype
 A0 = ((v4s ) (&A[0]);       A1 = ((v4s ) (&A[ldA] );
 A2 = ((v4s ) (&A[2*ldA]);   A3 = ((v4s ) (&A[3*ldA] );

 // Transposition of Ar omitted for brevity
 // ...
 for ( jr = 0; jr < nc; jr++ ) { // Loop L6
   // Load the jr-th columns of Cr, Br into two vector registers
   cr = ((v4s ) (&Cr[baseCB]);
   br = ((v4s ) (&Br[baseCB]);

   // Update i-th entry of cr as cr[i] += Ai * br, i=0,1,2,3,
   // The GAP8 dot product is realized in software via the
   // gap8_dotp4 instruction
   cr[0] += gap8_dotp4(A0, br); cr[1] += gap8_dotp4(A1, br);
   cr[2] += gap8_dotp4(A2, br); cr[3] += gap8_dotp4(A3, br);

   // Store the column of Cr in memory. No vector support in
GAP8
   Cr[baseCB+0] = cr[0]; Cr[baseCB+1] = cr[1];
   Cr[baseCB+2] = cr[2]; Cr[baseCB+3] = cr[3];

           baseCB += 4; // Prepare for next iteration
 }
```

Runtimes on Different micro-**kernel dimensions**



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