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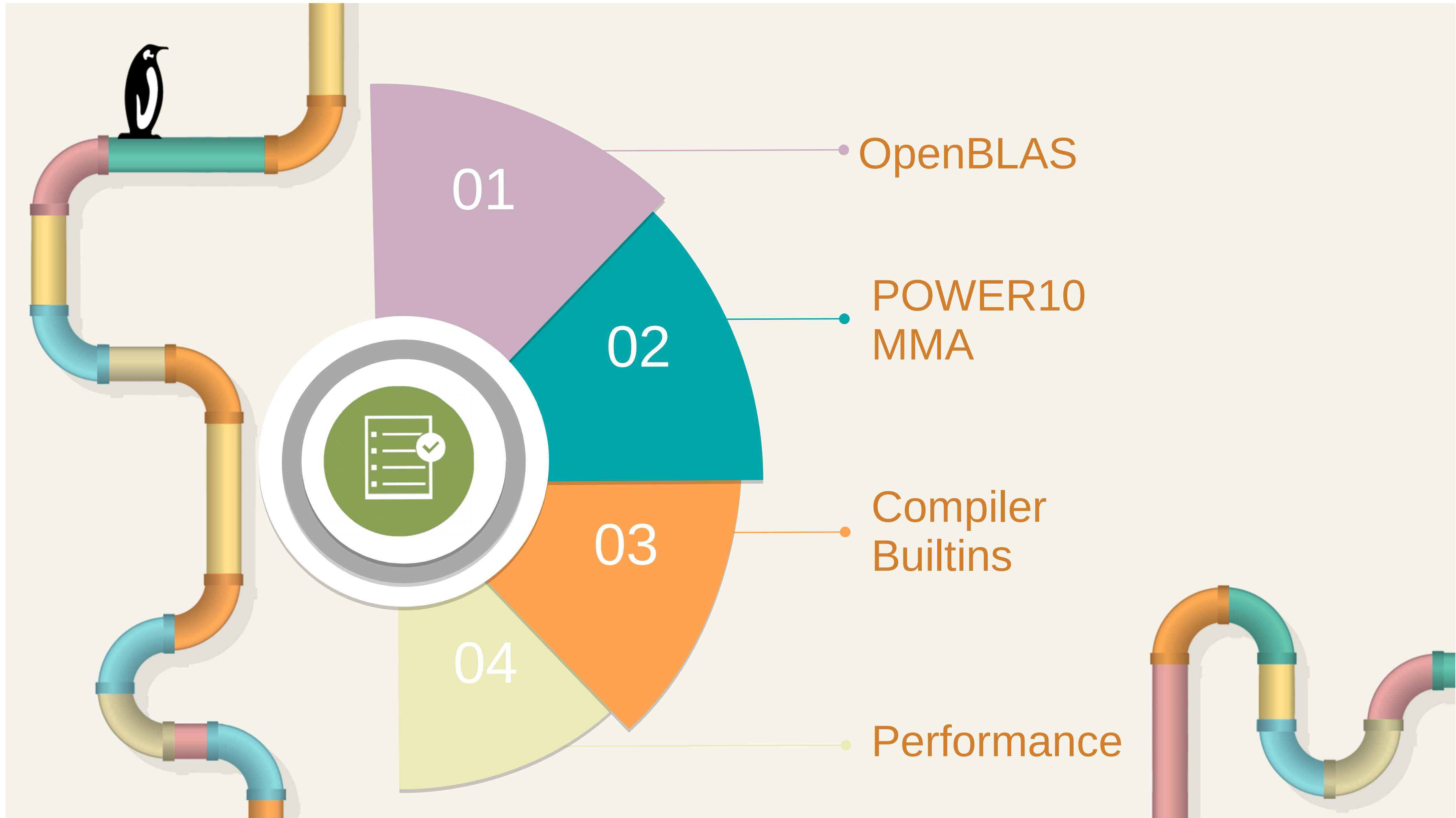
August 24-28, 2020

Accelerating ML workloads using new GCC builtins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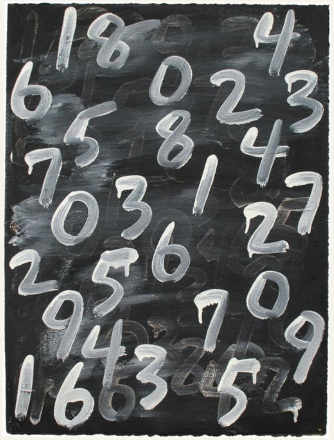
BLAS

The BLAS (Basic Linear Algebra Subprograms) are routines that provide standard building blocks for performing basic vector and matrix operations.

Level-1 BLAS perform scalar, vector and vector-vector operations

Level-2 BLAS perform matrix-vector operations

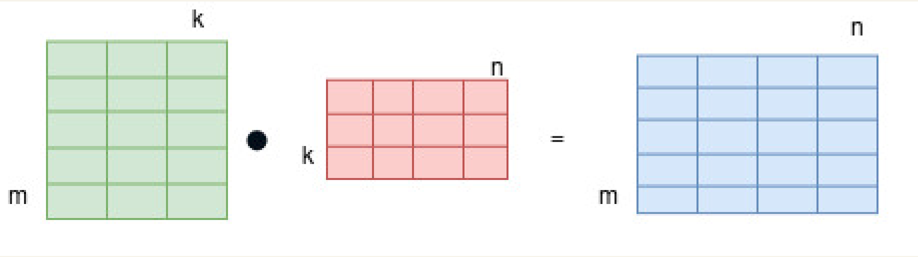
Level-3 BLAS perform matrix-matrix operations



OpenBLAS

An optimized BLAS library

- Optimized implementations of linear algebra kernels for several processor architectures.
- Default underlying library for many ML/DL frameworks.
- The source code distribution provides benchmarks for each BLAS kernel.
- Added **POWER10** support recently in OpenBLAS.
- Optimized GEMM [GEneral Matrix - Matrix] kernels.



POWER10 MMA

Most operations in training/inferencing in a neural network require some form of matrix multiplication.

Matrix Multiply Assist feature

- Eight 512 bit accumulators. Each accumulator contains four 128-bit rows

4X4 array of fp32-bit elements

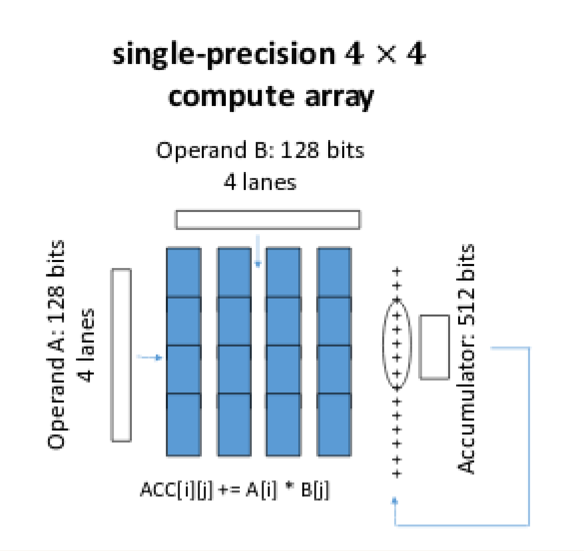
$$A = \begin{bmatrix} a_{00} & a_{01} & a_{02} & a_{03} \\ a_{10} & a_{11} & a_{12} & a_{13} \\ a_{20} & a_{21} & a_{22} & a_{23} \\ a_{30} & a_{31} & a_{32} & a_{33} \end{bmatrix}$$

4x2 array of fp64-bit

$$A = \begin{bmatrix} a_{00} & a_{01} \\ a_{10} & a_{11} \\ a_{20} & a_{21} \\ a_{30} & a_{31} \end{bmatrix}$$

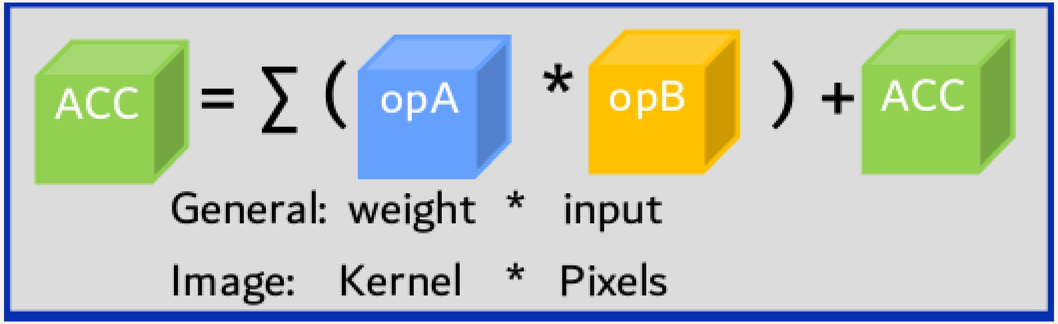
- A set of instructions to transfer data between vector-scalar registers and accumulators.
- A set of outer product instructions that perform an outer-product operation.

Outer-product (xv<type>ger<rank-k>) instructions



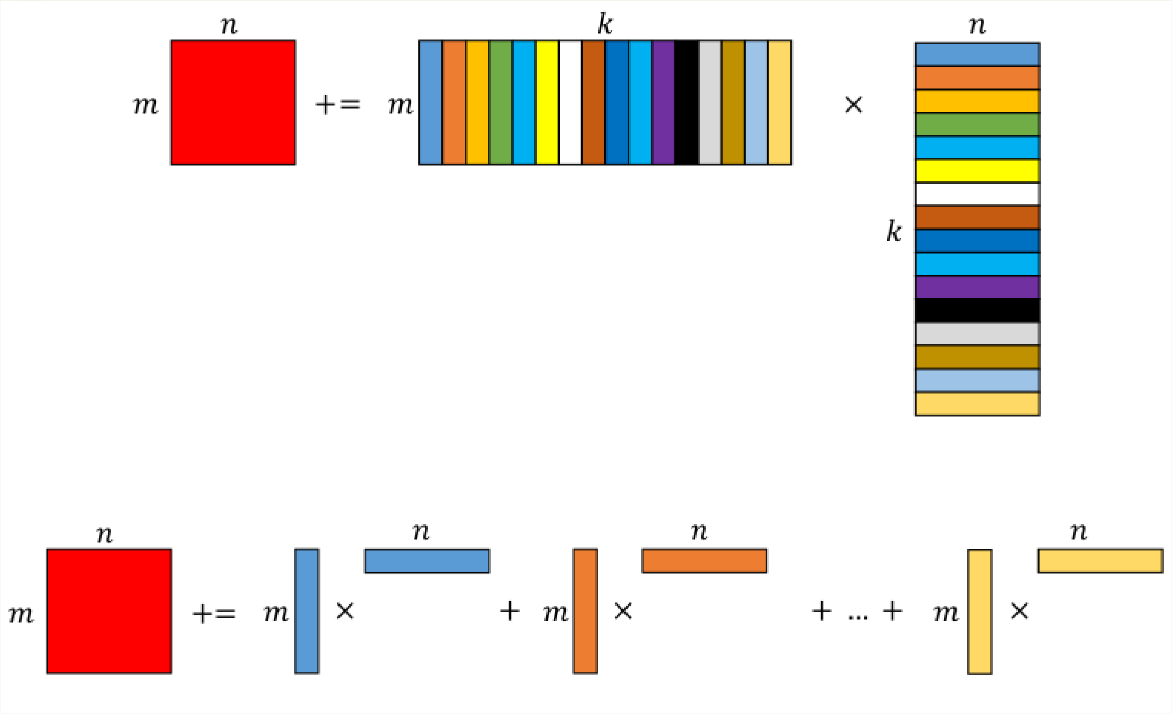
Accumulators are updated by rank-k update instructions:

- Input: 1 accumulator (A) + 2 VSRs (X, Y)
- Output: 1 accumulator (same as input to reduce instruction encoding space).



The **micro-kernel (innermost loop) of GEMM**

$C_{m\times n} \mathrel{+}= A_{m\times k} \times B_{k\times n}$



- Load a small, “square” panel of C and keep it in registers
- Load one small column of A and one small row of B
- Outer-product and accumulate
- Repeat!

Matrix-Multiply Assist Built-ins

- ISA 3.1 of the PowerPC added new Matrix-Multiply Assist (MMA) instructions
- GCC provides support for these instructions through the _builtin_mma_* built-in functions
- Some of the builtins used now in OpenBLAS are:

```
void __builtin_mma_xvbf16ger2 (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf32ger (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvbf16ger2pp (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf32gerpp (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf64ger (__vector_quad *, __vector_pair, vec_t);
void __builtin_mma_xvf64gerpp (__vector_quad *, __vector_pair, vec_t);
void __builtin_mma_xxmtacc (__vector_quad *);
void __builtin_mma_xxmfacc (__vector_quad *);
void __builtin_mma_xxsetaccz (__vector_quad *);
void __builtin_mma_disassemble_acc (void *, __vector_quad *);
void __builtin_mma_disassemble_pair (void *, __vector_pair *);
```

Using new MMA builtins

- Hand written assembly version used in previous versions for GEMM optimization.
- Started POWER10 optimization with assembly and later converted to C code using built ins.
- Lines of code reduced from 6K to 1K for inner gemm kernels.
- Performance is closer to assembly version.
- These builtins are also now used in Eigen.

* Up to 4x improvements noted in simulator depending on various factors compared to previous processor.

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Thank You!

References:

- https://gcc.gnu.org/onlinedocs/gcc/PowerPC-Matrix-Multiply-Assist-Built-in-Functions.html
- https://github.com/xianyi/OpenBLAS/tree/develop/kernel/power