# Mixed precision: when is it worth it?

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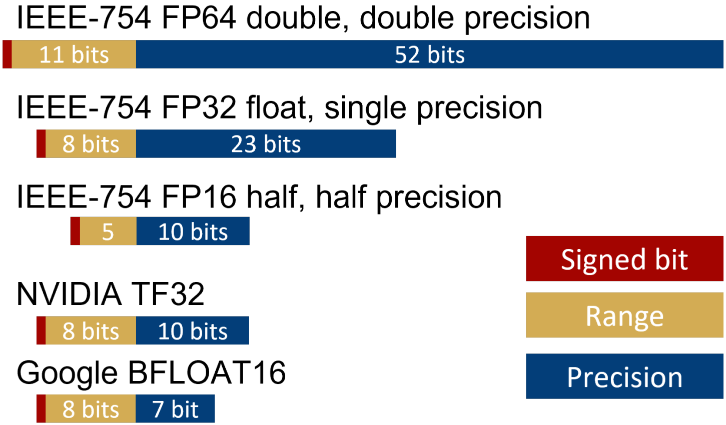
# Floating point representation



# Key challenges of exascale computing

In 2008 Exascale Study Group (ESG) issued a report: Technology Challenges in Achieving Exascale Systems [8]

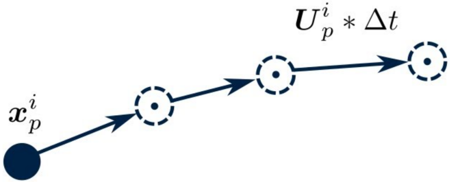
1. power consumption
   - 600 MW $\rightarrow$ 20 MW
2. speed and energy of data movement
   - time of data movement $>$ time of FLOP
3. fault tolerance
   - Failures happen faster, than checkpointing a job.
4. extreme parallelism
   - To compute at a rate of 1 exaflop requires 1 billion floating point units performing 1 billion calculations per second each

# Wide interest in mixed precision

- Less communication
  - Reduce memory traffic
  - Reduce network traffic
- Reduce memory footprint
- More Flop per second
  - Reduced energy consumption
  - Reduced time to compute

- Gordon Bell Prize winner climate simulation [9]
- Gordon Bell Prize winner opioid addiction research [7]
- Best paper at ISC'19 GPUMixer [10]
- Earthquake simulation [6]
- Mixed precision in-memory computing [11]
- AI, Deep learning [13], [12]
- Linear solvers, numerical methods [1], [2], [4]

# Particle method




Position: FP64
Displacement: FP32

# Machine learning [12]

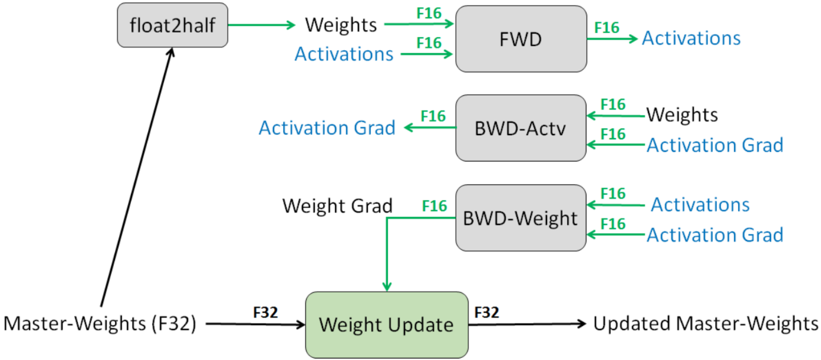



Figure: Mixed precision training iteration for a layer. Memory consumption of deep learning models nearly halved.

# Linear solver in Ginkgo[3]

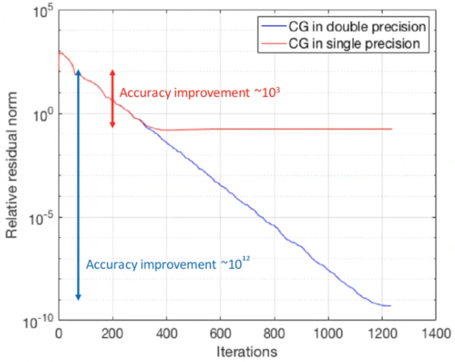
Linear system Ax=b
Rule of thumb [5]:

$$\text{relative residual accuracy} = (\text{unit round-off}) * (\text{linear system's condition number})$$

# Linear solver in Ginkgo[3]

Linear system Ax=b with cond(A)=4
Rule of thumb [5]:

relative residual accuracy = (unit round-off) $*$ (linear system's condition number)

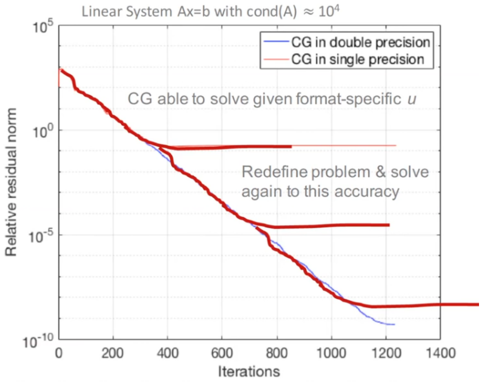


# Linear solver in Ginkgo[3]

Linear system Ax=b with cond(A)=4  16% runtime improvement

Rule of thumb [5]:

$$\text{relative residual accuracy} = (\text{unit round-off}) * (\text{linear system's condition number})$$



# GPUMixer [10]

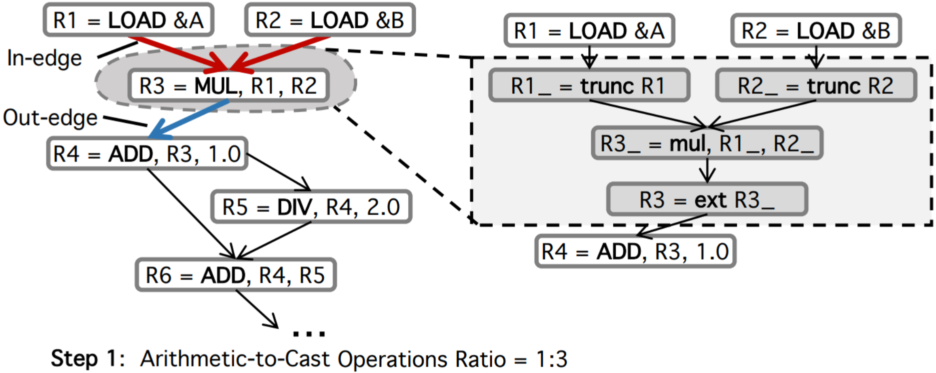



Figure: Illustration of the algorithm to find Fast Imprecise Sets (FISets)

# GPUMixer [10]

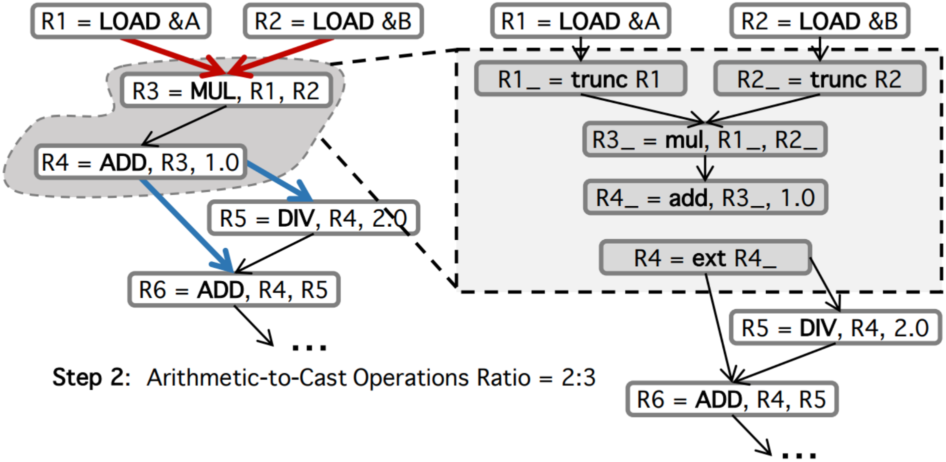



Figure: Illustration of the algorithm to find Fast Imprecise Sets (FISets)

# GPUMixer [10]

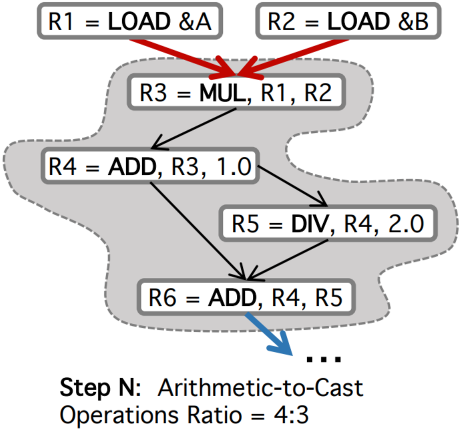
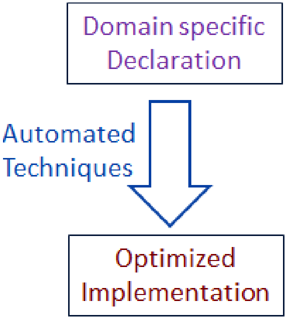



Figure: Illustration of the algorithm to find Fast Imprecise Sets (FISets) 46.4% of the ideal speedup

One approach to develop future proof HPC applications is the use of domain specific high-level abstractions (HLAs)

- Provide the application developer with a domain specific abstraction
  - To declare the problem to be computed
  - Without specifying its implementation
  - Use domain specific constructs in the declaration
- Create a lower implementation level
  - To apply automated techniques for translating the specification to different implementations
  - Target different hardware and software platforms
  - Exploit domain knowledge for better optimisations on each hardware system

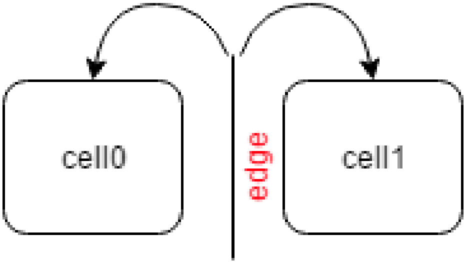


# OP2

- Open Source project
- OP2 based on OPlus (**O**xford **P**arallel **L**ibrary for **U**nstructured **S**olvers), developed for CFD codes on distributed memory clusters
- Separate high level description from parallel implementation
- Looks like a conventional library, but uses code transformations (source to source translator) to generate parallel codes
- Support application codes written in C++ or FORTRAN

## OP2 loop over edges

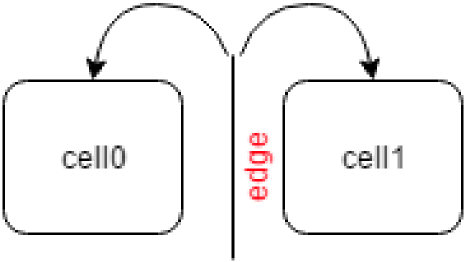
```
void res(double* edge,
         double* cell0,
         double* cell1){
   *cell0 += *edge;
   *cell1 += *edge;
}
```




```
op_par_loop(res,"residual_calculation", edges,
  op_arg(dedges, -1, OP_ID, 1, "double", %OP_READ),
  op_arg(dcells, 0, pecell, 1, "double", OP_INC),
  op_arg(dcells, 1, pecell, 1, "double", OP_INC));
```

## OP2 loop over edges

```
void res(double* edge,
        float* cell0,
        float* cell1){
   *cell0 += *edge;
   *cell1 += *edge;
}
```




```
op_par_loop(res,"residual_calculation", edges,
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  op_arg(dcells, 0, pecell, 1, "float", OP_INC),
  op_arg(dcells, 1, pecell, 1, "float", OP_INC));
```

# Example test

- CPU related environment
  - Intel(R) Xeon(R) Gold 6226R CPU @ 2.90GHz with 64 processes
- GPU related environment
  - dgx-station with 2 Nvidia V100 GPUs

- Test application
  - **Airfoil**, a standard finite volume CFD benchmark code with a 2.8M mesh size

| Environment | FP64 | FP32 | Mixed | speedup - mixed | speedup - float |
|---|---|---|---|---|---|
| Intel | 14.44s | 8.22s | 12.76s | 1.13 | 1.76 |
| Nvidia | 2.17s | 1.51s | 1.97s | 1.1 | 1.44 |

# Contact

- **OP-DSLs**: `https://op-dsl.github.io/`
- **OP2**: `https://github.com/OP-DSL/OP2-Common`
- siklosi.balint@itk.ppke.hu

Új Nemzeti Kiválóság Program

INNOVÁCIÓS ÉS TECHNOLÓGIAI MINISZTÉRIUM

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