



Loops of the Domain-specific Programming Language DaphneDSL

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- DAPHNE - integrated Data Analysis Pipelines for large-scale data management, Highperformance computing, and machiNE learning
- Open source: <https://github.com/daphne-eu/daphne/>
- DaphneDSL
 - variables, data types,
 - comments, expressions,
 - control structures,
 - loops, function, etc.



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System Architecture

- Execution environment – the flows and operations as defined in the DaphneDSL
- Multi-level translation
- Multi-Level Intermediate Representation MLIR
 - Extensible compilers
 - Fragmented software
 - Compiling for heterogeneous hardware
 - Linking compilers
- DaphneDSL scripts => DaphneIR intermediate (MLIR)
- Efficient pipeline design and kernel execution



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Program for calculating the sum of the first 1000 natural numbers.

```
# File:  program.daphne
# Initialization
sum = 0;

# Calculation of sum
for (i in 1:1000) {
    sum = sum + i;
}

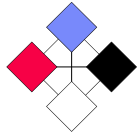
# Output result
print("Sum is: "+sum);
```

Parsing, compiling and running the program.

```
$ bin/daphne program.daphne
$ Sum is: 500500
```



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DAPHNE

DaphneIR dialect

```
module {
func.func @main() {
  %0="daphne.constant"(){value = 0 : si64}:() -> si64
  %1="daphne.constant"(){value = "Sum is: "}:()->!daphne.String
  ...
  %11=scf.for %arg0=%6 to %5 step %6 iter_args(%arg1=%0)->(si64){
    %c1.i32=arith.constant 1:i32
    %14="daphne.call_kernel"(%arg0,%c1.i32,%10){callee=
      "_cast__int64_t__size_t":(index,i32,!daphne.DaphneContext)->si64
    %c2.i32=arith.constant 2:i32
    %15="daphne.call_kernel"(%14,%4,%c2.i32,%10){callee=
      "_ewMul__int64_t__int64_t__int64_t":
      (si64,si64,i32,!daphne.DaphneContext)->si64
    %c3.i32=arith.constant 3:i32
    %16="daphne.call_kernel"(%arg1,%15,%c3.i32,%10){callee=
      "_ewAdd__int64_t__int64_t__int64_t":
      (si64,si64,i32,!daphne.DaphneContext)->si64
    scf.yield %16:si64
  }
  ...
}
```



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Low-Autocorrelation Binary Sequences

$$Z_L = \{z_1, z_2, \dots, z_L\}; z_i \in \{+1, -1\}$$

$$E(Z_L) = \sum_{k=1}^{L-1} C_k^2$$

$$C_k(Z_L) = \sum_{i=1}^{L-k} z_i \cdot z_{i+k}$$

$$Z_L^* = \arg \min_{Z_L \in B_L} E(Z_L)$$

```
def calcE(s:matrix<si64>,L:ui64) ->
ui64 {
  E=as.ui64(0);
  for(k in 1:L - 1) {
    ck=as.si64(0);
    for(i in 0:L - k - 1) {
      ck=ck+as.si64(
        as.scalar(s[i,]*s[i+k,]));
    }
    tmp = as.ui64(ck*ck);
    E = E + tmp;
  }
  return E;
}

for (L in 5:301) {
  s = sample(2,L,true,-1);
  s = 2*s - 1;
  E = calcE(s,as.ui64(L));
  print("L="+L+" E="+E);
}
```



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Loops in the DaphneDSL

- A simple syntax
- Similar to programming languages, such as C++ and R
- Shorter and more expressive programs
- Larger number of iterations
 - Summarize the natural numbers up to the number 174,355
 - Calculated the energies for sequences of lengths up to $L = 192$



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Stack size used by the program

- \$ ulimit -s unlimited
- Summarize the natural numbers up to the number 10,000,000
- Calculated the energies for sequences of lengths up to $L = 1000$
- Developer quickly fixed the issue #77
- Open source code



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Conclusion

- DAPHNE project
- System Architecture
- Two examples of using DaphneDSL
- Loops in the DaphneDSL
- Quickly fixed the issue #77 (open source code)
- The DAPHNE code is more and more reliable and valuable over time



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