CUDAnative.jl

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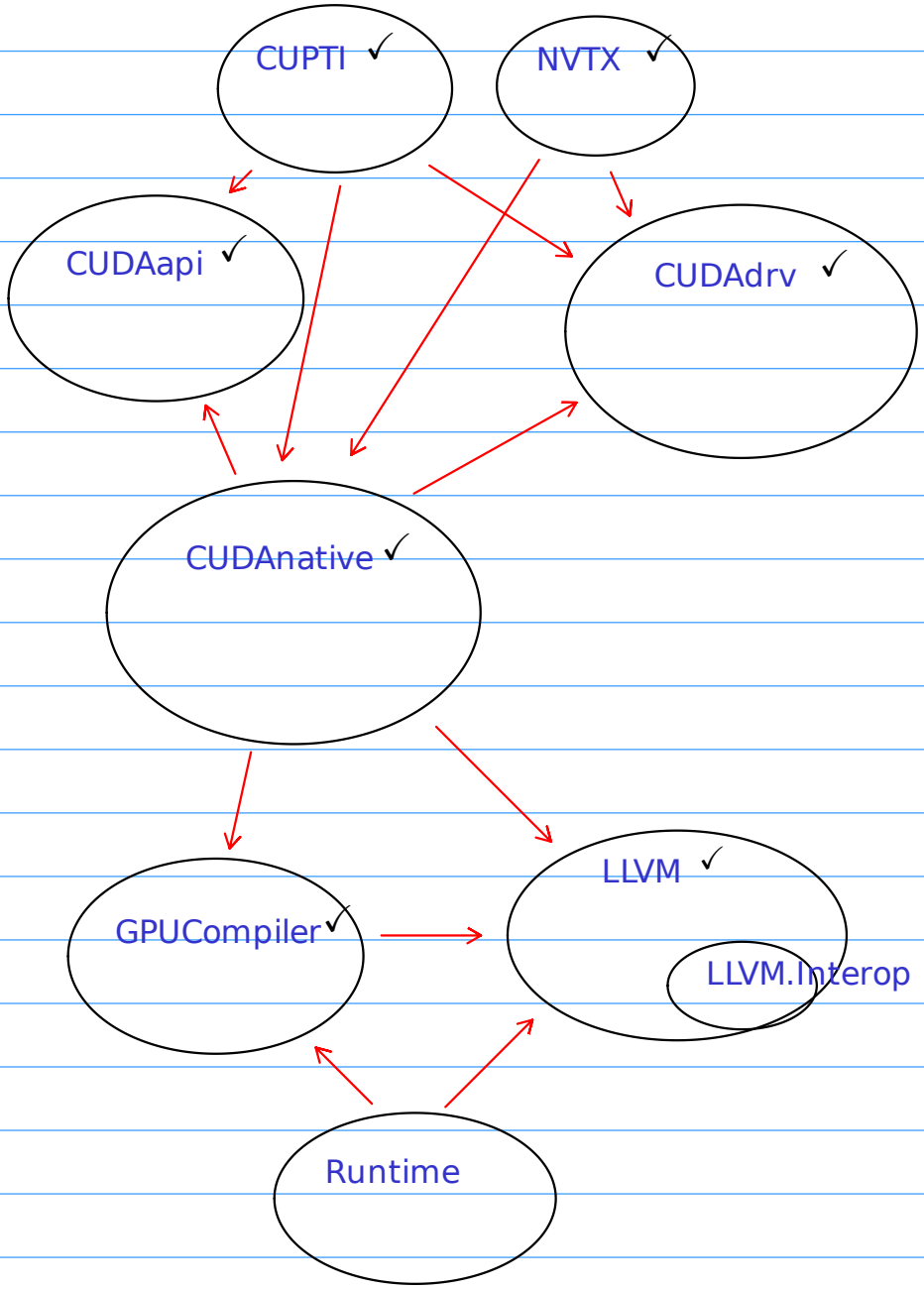
CUPTI: CUDA Profiling Tools Interface
NVTX: NVIDIA Tools Extension SDK

GPUのperf counter群を扱うhigh-level API?
annotationして超高級printf debugみたいな?



module 相関図

Why LLVM.jl

The high level Julia IR is accessible with the code_lowered and code_typed reflection functions, and can be modified with generated functions.

Low-level LLVM IR can be inspected by invoking code_llvm and injected via the llvmcall metaprogramming interface. Machine code is accessible through code_native and can be inserted indirectly as inline assembly in LLVM IR.

LLVM IR への interface は string based

例えばpointerを指定してloadする関数をstring-basedで書いたらその関数はstring操作で溢れて読めたもんじゃないし各pointer typeを個別に扱ってoptimizeするようなはめに陥るだろう

```
julia> using LLVM
julia> mod = LLVM.Module("llvmcall")
; ModuleID = 'llvmcall'
source_filename = "llvmcall"
julia> eltyp = LLVM.convert(LLVMType,Int64)
i64
julia> pram_typs = [LLVM.PointerType(eltyp)]
1-element Array{LLVM.PointerType,1}:
 i64*
julia> ft = LLVM.FunctionType(eltyp, pram_typs)
i64 (i64*)


julia> LLVM.Builder() do builder
           bb = LLVM.BasicBlock(f, "entry")
           LLVM.position!(builder, bb)
           ptr = LLVM.parameters(f)[1]
           val = LLVM.load!(builder, ptr)
           LLVM.ret!(builder, val)
       end
  ret i64 %1


julia> f

define i64 @load(i64*) {
entry:
  %1 = load i64, i64* %0
  ret i64 %1
}
```

LLVM.jl

lib/
@apicall(:LLVMなんたらかんたら , ...) C function? Clang.jlで生成?

wrap/wrap.jl
llvm-configを走らせてheaderを生成したりする?

src almost except LLVM.jl are LLVM API wrappers
```
├── LLVM.jl
├── analysis.jl
├── base.jl
├── bitcode.jl
├── buffer.jl
├── core
├── core.jl
├── datalayout.jl
├── debuginfo.jl
├── deprecated.jl
├── execution.jl
├── init.jl
├── interop
├── interop.jl
├── ir.jl
├── irbuilder.jl
├── linker.jl
├── moduleprovider.jl
├── pass.jl
├── passmanager.jl
├── passregistry.jl
├── support.jl
├── target.jl
├── targetmachine.jl
├── transform.jl
├── types.jl
└── util
```
base: Define @apicall

```
libllvm_paths = filter(Libdl.dllist()) do lib
    occursin("LLVM", basename(lib))
end
```
filter ideom

new{T,S} return something{T,S} type object

GPUCompiler.jl

@kwdef typedef
  automatically defines a keyword-based constructor

  ptx.jl hide_trap!
    pass removes calls to `trap` and replaces them with inline assembly

CUDAnative.jl

  CUDAnative.jl のすること:
   CUDAのconfigurationをcheck
   device/*.jl を include
   CUDACompilerTarget, CUDACompilerJob を定義
   *.jl を include
   initialization
     __init__(), __configure__(), __runtime_init__()

  device/tools.jl Create MDNodes
  device/pointer.jl Pointers with address space information, AS module, DevicePtr...
      Generate LLVM IR for memory oparation
  device/array.jl Contiguous on-device arrays
  device/cuda.jl Include device/cuda/*.jl
  device/llvm.jl   wrappers for LLVM-specific functionality: trap(), assume()

                                                                ?bitcast

 init.jl   CUDA Initialization and Context Management
   context, context!, device!, device_reset!
   CUDAnative.attaskswitch, CUDAnative.atcontextswitch
 compatibility.jl Julia, CUDA and LLVM version compatibility
 bindeps.jl   CUDA discovery and dependency

 cuoti/CUPTI.jl
 nvtx/NVTX.jl   Wrappers for CUPTI and NVTX

  execution.jl   @cuda
  exceptions.jl   device-side exceptions
  reflection.jl   @device_code_*
  array.jl   CUDA host array type for testing purposes

  deprecated.jl

device/cuda/*.jl

memory_shared.jl
@cuStaticSharedMem(T::Type, dims) -> CuDeviceArray{T,AS.Shared}
@cuDynamicSharedMem(T::Type, dims, offset::Integer=0) -> CuDeviceArray{T,AS.S
These 2 call _shmem @generated function which creates llvm function call so to
returns a pointer to shared memory.

indexing.jl
threadIdx, blockDim, blockIdx, gridDim, warpsize
llvm.nvvm.read.ptx.sreg.tid.x などを呼ぶ generated function で
llvm.nvvm.read.ptx.sreg.warpsize を ccall

ATM, values are based on V100

synchronization.jl
sync_threads, sync_warp,
sync_threads_count, sync_threads_and, sync_threads_or
threadfence, threadfence_block, threadfence_system
llvm.nvvm.* function を ccall

warp_vote.jl
vote_all, vote_any, vote_ballot
@asmcallでPTXのvote insnを呼び出し

warp_shuffle.jl
llvm.nvvm.shfl.sync.$mode.$typ intrinsicをccallする関数群を生成

output.j
@cuprintf
Print a formatted string in device context on the host standard output.
@cuprint, @cuprintln
Print a textual representation of args to standard output from the GPU.

$(map(esc, args)...)

asserstion.jl
@cuassert
@assert cond [text]

[continued]

memory_dynamic.jl
  malloc

atomics.jl
  ##LLVM
  @generated function llvm_atomic_op(::Val{binop}, ptr::DevicePtr{T,A}, val::T)
    where {binop, T, A}
   arithmetic operations on integers using LLVM instructions
  @generated function llvm_atomic_cas(ptr::DevicePtr{T,A}, cmp::T, val::T)
    where {T, A}
  ##NVVM
  @llvm.nvvm.atomic.load.add.*
  @llvm.nvvm.atomic.load.inc.*
  @llvm.nvvm.atomic.load.dec.*
  ##Julia
  atomic_*!()
  # Higher level interface
  @atomic a[I] = op(a[I], val)
  @atomic a[I] ...= val

misc.jl
  clock, nanosleep
    llvm.nvvm.read.ptx.sreg.clock64 and nanosleep.u32 insn

wmma.jl
  Warp Matrix Multiply Accumulate ???

" The libdevice library is a collection of NVVM bitcode functions that implement common functions for NVIDIA GPU devices, including math primitives and bit-manipulation functions. These functions are optimized for particular GPU architectures, and are intended to be linked with an NVVM IR module during compilation to PTX."

 math.jl

" The libcudadevrt library is a collection of PTX bitcode functions that implement parts of the CUDA API for execution on the device, such as device synchronization primitives, dynamic kernel APIs, etc."

libcudadevrt_common.jl, libvudadevrt.jl : cuda_device_runtime_api

cooperative_groups.jl
  this_grid, sync_grid

dynamic_parallelism.jl
  launch, synchronize

CUDAdrv.jl

CUDAdrv.jl のすること

pointer.jl がessential functionality
  CuPtr{T}, PtrOrCuPtr{T}
各種wrapperをincludeする　　Do init that can't be done at module load time
deffered initialization
initialization
  __configure__() which is essentially ccall of cuInit

low-level wrappers
libcuda_common.jl
error.jl　　CuError, CUDAdrv.initializer(f::Function)
libcuda.jl　　wrapper gened from cuda.h
libcuda_aliases.jl　　Remove _v2 postfix

high-level wrappers
version.jl　　version() and release() of CUDA
devices.jl　　CuDevice, name, totalmem, attribute,...
context.jl　　CuContext,...
context/primary.jl　　CuPrimaryContext
stream.jl　　CuStream,...
memory.jl　　Mem, Mem.DeviceBuffer, Mem.Device,
　　Mem.alloc, Mem.[un]register, Mem.free, copy...
module.jl　　include module/jit.jl　　encode/decode JIT options
　　CuModule, CuModuleFile
　　include module/function.jl　　CuFunction
　　include module/global.jl　　CuGlobal, get, set
　　include module/linker.jl　　CuLink,...
events.jl　　CuEvent, record, synchronize, elapsed
execution.jl　　CuDim, cudacall
　　cudacall calls launch() with convert_argument
profile.jl　　profiling with Nsight/NVTX or with external profiler
occupancy.jl　　active_blocks, occupancy, launch_configuration

deprecated.jl

cuXXXはCUDA_driver, cudaXXXはCUDA_runtime

CUDAapi.jl

CUDAのinstall状況を知る+お役立ちmodule

CUDAapi.jl includes

util.jl	@enum_without_prefix
discovery.jl	find_cuda_library, find_cuda_binary, find_toolkit, parse_toolkit_version, find_libdevice, find_libcudadevrt
availability.jl	has_cuda, has_cuda_gpu, usable_cuda_gpus call find_toolkit and ccall cuDeviceGetCount
complex.jl	Define cuda complex types
library_types.jl	Other cuda data types
call.jl	@runtime_ccall, decode_ccall_function, @checked ccall extention wrappers

GPUCompiler.jl Take2

GPUCompiler.jl includes *.jl below

utils.jl tbaa_make_child child用LLVM metadata nodeを返す? TBAA???

compiler interface and implementations
interface.jl target-specific interface for packages to implement
FunctionSpec function,kernelのaggregate type
CompilerTarget, CompilerJob abstractな操作
error.jl error handling
KernelError, InternalCompilerError
native.jl native target(Sys.MACHINE) for CPU execution
NativeCompilerTarget,NativeCompilerJob
ptx.jl PTX target(nvptx64-nvidia-cuda) for GPU execution
PTXCompilerTarget,PTXCompilerJob
ここは大変
gcn.jl GCN target(amdgcn-amd-amdhsa) for GPU execution
GCNCompilerTarget,GCNCompilerJob

runtime.jl GPU のruntimeで必要なJulia runtime functions [module Runtile]
それらの関数はRuntimeMethodInstanceとして保持される. もしその関数が
targetで規定されるものならUndefVarErrorを避けるためllvmcall stubを生成する
malloc, box, unboxなどのsupportもここで

compiler implementation
irgen.jl LLVM IR generation
compile_method_instance LLVM IRを生成しLLVM moduleを作って返す
irgen さらにtarget-specific processingやentryの処理などを行う
promote_kernel! promote a function to a kernel

optim.jl LLVM IR optimization, kernel lowering
validation.jl Validate method, IR, ...
rtlib.jl Compiler support for GPU runtime library
mcgen.jl final preparations for the module to be compiled to PTX
debug.jl backtrace
driver.jl Compiler driver and main interface: compile() which calls
codegen() which makes passes run これが大枠

other reusable functionality
cache.jl Compilation cache
execution.jl Helper to implement code exec. split_kwargs, assign_args!
reflection.jl code_*, device_code_*