F# OpenCL C Type Provider

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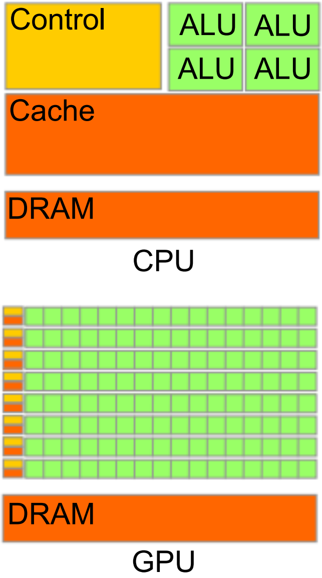
GPGPU



General purpose computations on graphical processor units

- (Almost) SIMD architecture
- Huge amount of “simple” ALUs on single chip
- Initially for computer graphic/games etc
- Good choice for massive data processing

General purpose applications of GPGPU

- Initially for scientific computations
  - Physics
  - Math
  - Chemistry
- But more and more for applications
  - Finance/Banking
  - Data Analytics and Data Science (Hadoop, Spark ...)
  - Security analytics (log processing)
  - Some "scientific computations" today are daily-used applications (bioinformatics, chemistry , . . .)

High level languages and GPGPU

Low-level platforms and languages for GPGPU programming

- NVIDIA CUDA: Cuda C, Cuda Fortran
- **OpenCL: OpenCL C**

High-level platform and languages for applications

- C++
- Python, Haskell, OCaml, ...
- JVM: Java, Scala, ...
- **.NET: C#, F#, ...**

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Interaction is a problem!

Possible solutions

- Translation of high-level language to GPGPU specific one
  - \+ Useful features of host language for GPGPU programming (type safety, etc)
  - \- High performance GPGPU programs is inherently low-level
- Reusing of existing GPGPU libraries
  - \+ GPGPU optimized solution in low-level language
  - ? We need automatic generation of "well-typed" bindings

Brahma.FSharp

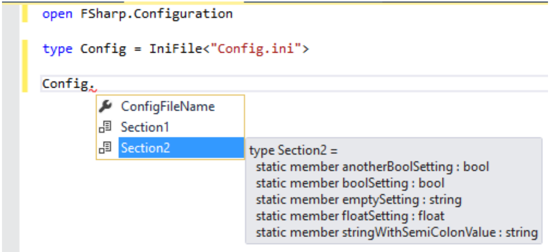
- F# quotations to OpenCL C translator
- Runtime
  - Comand queue
  - Execution context management
  - Memory management
  - F# aliases for OpenCL-specific functions

F# type providers

- Compile-time metaprogramming technique for compile-time types creation
  - Type provider is a “function which constructs type”
- Design-time features in IDE
  - Completion
  - Type information
- Used for type-safe integration of external data with “fixed schema”
  - Type providers for XML, JSON, INI, etc
  - R, SQL, etc type providers

Example of INI type provider

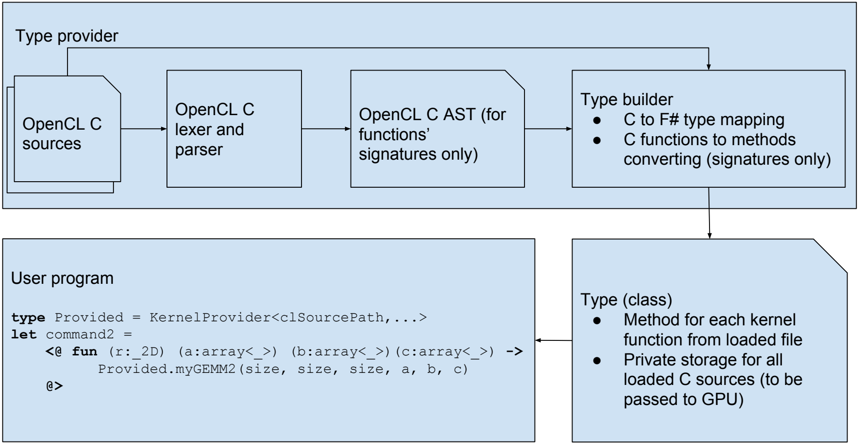
```
[Section1]
intSetting = 2
stringSetting = stringValue
[Section2]
floatSetting = 1.23
boolSetting = true
anotherBoolSetting = False
emptySetting =
stringWithSemiColonValue = DataSource=foo@bar;UserName=blah
```



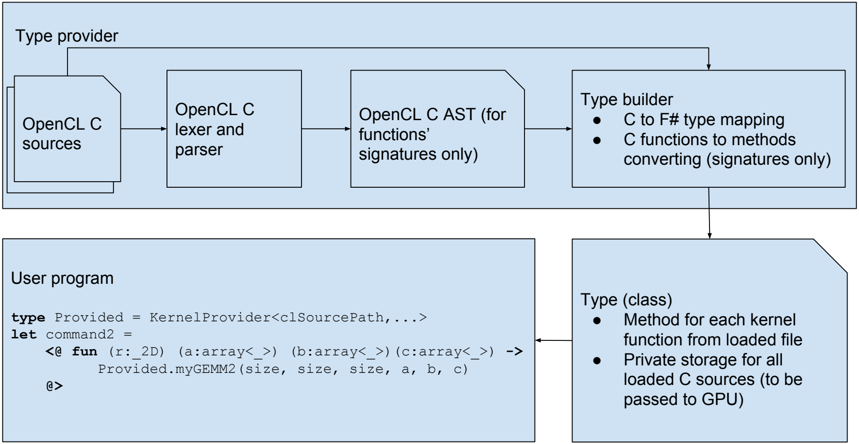
OpenCL C type provider

- We want to construct type-safe wrapper for given library
- OpenCL standard declares source-level distribution with "in place" compilation
  + We can work with source code (text), not with binaries
  - "Existing library" is a set of files includes *.h files
- Functions signatures processing should be enough for basic integration

OpenCL C type provider: architecture



OpenCL C type provider: architecture



Yes, it is typical type provider

Limitations

- Only (small) subset of OpenCL C
  - h files is not supported
  - preprocessor is not supported
  - only small subset of syntax is supported
- Very simple C to F# type mapping
- ...

Examples

```
// TypeProvider configuration
let constantsPath = __SOURCE_DIRECTORY__ + "/constants.h"
let [<Literal>] clSourcePath = __SOURCE_DIRECTORY__ + "/mygemm.c"
type ProvidedType = KernelProvider<clSourcePath, TreatPointersAsArrays=true>
```

```
let command2 =
    <@
        fun (r:_2D) (a:array<_>) (b:array<_>) (c:array<_>) ->
            ProvidedType.
    @>
```

myGEMM1 — KernelProvider<...>.myGEMM1(M: int, N: int, K: int, A: float32 [], B: float32 [], C: float32 []) : unit
myGEMM2
myGEMM3
myGEMM5

```
let command2 =
    <@
        fun (r:_2D) (a:array<_>) (b:array<_>) (c:array<_>) ->
            ProvidedType.myGEMM2(newSize, size, size, a, b, c)
    @>
```

This expression was expected to have type
  int
but here has type
  float

Future work

- Improve OpenCL C support
  - Lexer and parser
  - Translator
  - Types mapping
  - Headers files processing
  - ...
- Unify kernels on client side
  - Currently native Brahma.FSharp's kernel and kernel loaded by type provider are different types
- Improve mechanism of kernels composition

Summary

- F# OpenCL C type provider
  - Type-safe integration of existing OpenCL C code in F# applications
  - Prototype with limitations

- Source code on GitHub:
  `https://github.com/YaccConstructor/Brahma.FSharp`
- Package on NuGet:
  `https://www.nuget.org/packages/Brahma.FSharp/`

Contact Information

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- Brahma.FSharp: https://github.com/YaccConstructor/Brahma.FSharp

Thanks!