Let's Talk About Foreign Functions In Java

Deepu K Sasidharan

@deepu105 | deepu.tech

Deepu K Sasidharan

JHipster co-lead developer

Creator of KDash, JDL Studio

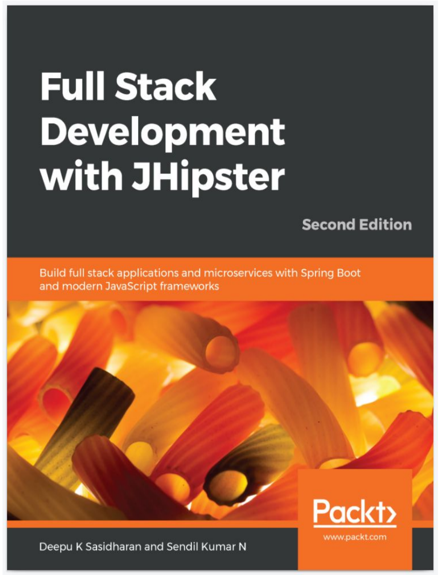
Developer Advocate @ Okta

OSS aficionado, author, speaker, polyglot dev

@deepu105

deepu.tech

DEV deepu105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Deepu K Sasidharan and Sendil Kumar N

What is FFI

Foreign Function Interface (FFI)

- Call routines from another program regardless of the language
- Most modern languages provide this feature in intuitive ways
- Term originated from common LISP
- Most languages use C/C++ calling conventions

Why FFI

- Interact with legacy apps
- Access features not available in the language
- Use native libraries
- Access functions or programs on the host OS
- GPU and CPU offloading (Cuda, OpenCL, OpenGL, Vulcan, DirectX…)
- Multiprecision arithmetic, Matrix multiplications
- Deep learning (Tensorflow, cuDNN, Blas…)
- OpenSSL, V8, and many more

A history of FFI in Java

Java Native Interface (JNI)

- Native interface access for C/C++/Assembly
- Fastest solution in Java
- Complicated to use and brittle
- Not very secure and could cause memory safety issues
- Overhead and performance loss is possible
- Difficult to debug
- Depends on Java devs to write safe C binding code manually

Java Native Access (JNA)

- Native interface access for C/C++/Assembly
- Much simpler to use
- Dynamic binding. No need to write any C binding code
- Widely used and mature library
- Uses reflection
- Built on top of JNI
- Has performance overhead and can be slower than JNI
- Difficult to debug

https://github.com/java-native-access/jna

Java Native Runtime (JNR)

- Native interface access for C/C++/Assembly
- Easy to use
- Dynamic binding. No need to write any C binding code
- Modern API
- Comparable performance to JNI
- Built on top of JNI
- Difficult to debug

https://github.com/jnr/jnr-ffi

Project Panama

https://foojay.io/today/project-panama-for-newbies-part-1/

Foreign-Memory Access API

- Safely and efficiently access foreign memory outside of the Java heap
  - Consistent API for different types of memory
  - JVM memory safety should not be compromised
  - Explicit memory deallocation
  - Interact with different kinds of memory resources, including off-heap or native memory.
- JEP-370 - First incubator in JDK 14
- JEP-383 - Second incubator in JDK 15
- JEP-393 - Third incubator in JDK 16
- Combined as Foreign Function & Memory API

Foreign Linker API

- API for statically-typed, pure-Java access to native code
    - Focus on Ease of use, flexibility and performance
    - Initial support for C interop
    - Call native code in a .dll/.so/.dylib
    - Create a native function pointer to a Java method which can be passed to code in a native library
- JEP-389 - First incubator in JDK 16
- Combined as Foreign Function & Memory API

Vector API

- API for reliable and performant vector computations
  - Platform agnostic
  - Clear and concise API
  - Reliable runtime compilation and performance
  - Graceful degradations
- JEP-338 - First incubator in JDK 16
- JEP-414 - Second incubator in JDK 7
- JEP-417 - Third incubator in JDK 18

Foreign Function & Memory API

- Evolution of the Foreign-Memory Access API and the Foreign Linker API
  - Same goals and features as the original two (Ease of use, safety, performance, generality)
- JEP-412 - First incubator in JDK 17
- JEP-419 - Second incubator in JDK 18

Jextract

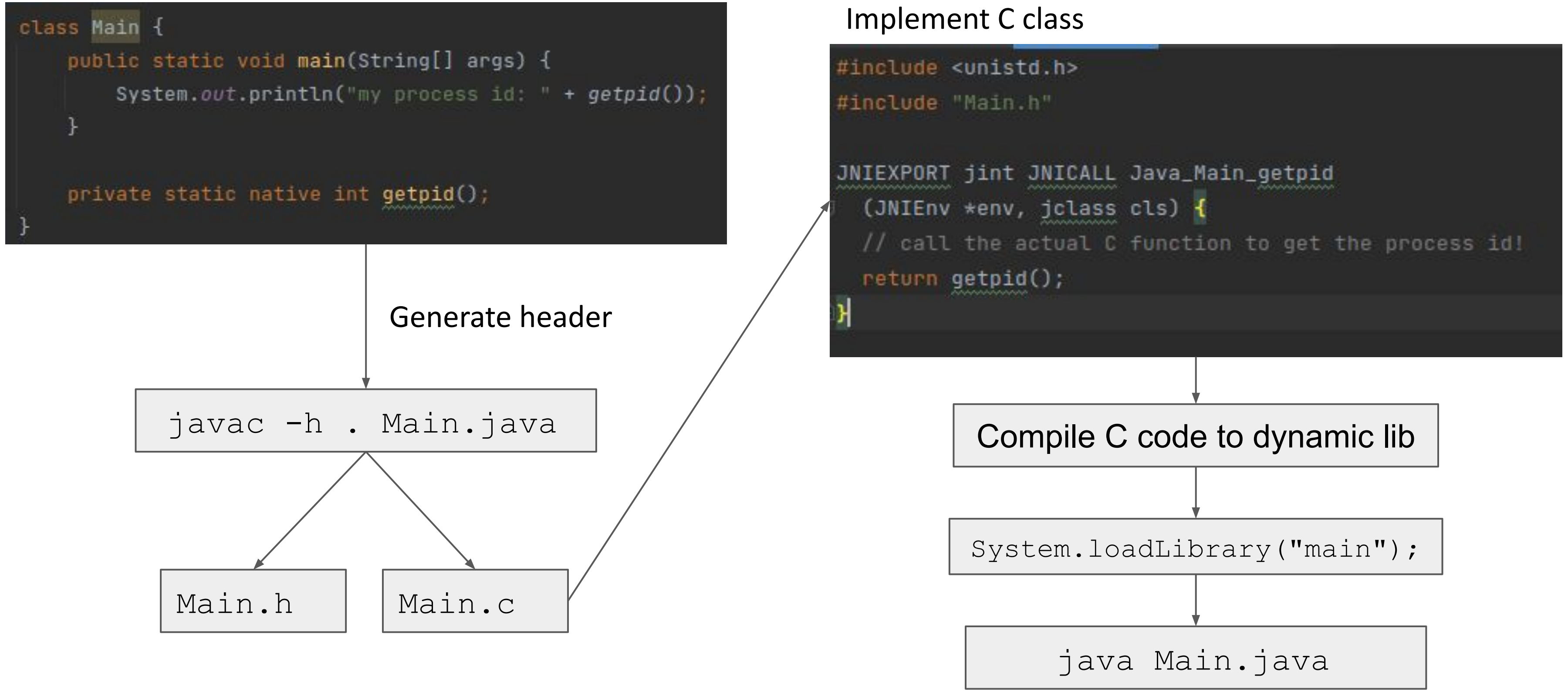
- A simple command line tool
- Generates a Java API from one or more native C headers
- Shipped with OpenJDK Panama builds
- Makes working with large C headers a cakewalk

Generate Java API for OpenGL

```
jextract --source -t org.opengl \
  -I /usr/include /usr/include/GL/glut.h
```

JNI vs Panama

getpid with JNI



```java
class Main {
    public static void main(String[] args) {
        System.out.println("my process id: " + getpid());
    }

    private static native int getpid();
}
```

Generate header

```
javac -h . Main.java
```

```
Main.h
```

```
Main.c
```

Implement C class

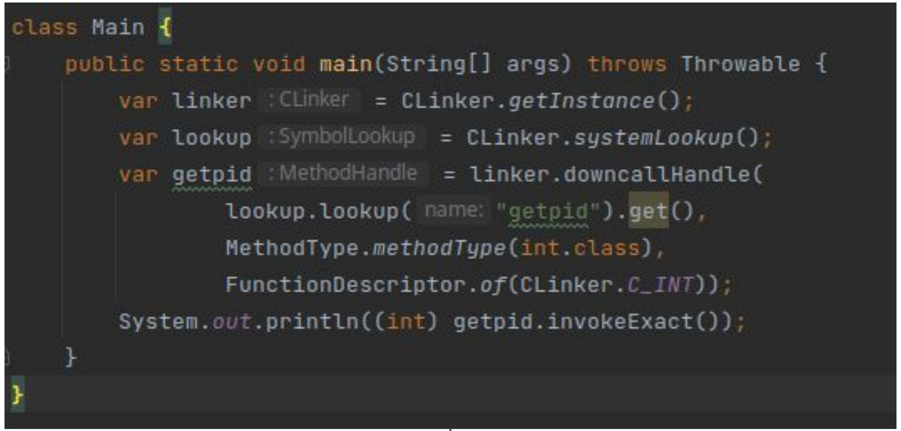
```c
#include <unistd.h>
#include "Main.h"

JNIEXPORT jint JNICALL Java_Main_getpid
  (JNIEnv *env, jclass cls) {
  // call the actual C function to get the process id!
  return getpid();
}
```

Compile C code to dynamic lib

```java
System.loadLibrary("main");
```

```
java Main.java
```

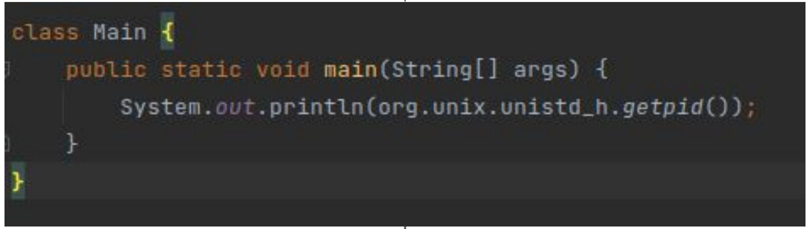
getpid with Panama (2 ways)



```java
class Main {
    public static void main(String[] args) throws Throwable {
        var linker = CLinker.getInstance();
        var lookup = CLinker.systemLookup();
        var getpid = linker.downcallHandle(
                lookup.lookup("getpid").get(),
                MethodType.methodType(int.class),
                FunctionDescriptor.of(CLinker.C_INT));
        System.out.println((int) getpid.invokeExact());
    }
}
```

```
java Main.java
```

```
jextract --source -t org.unix \
  -I /usr/include /usr/include/unistd.h
```



```java
class Main {
    public static void main(String[] args) {
        System.out.println(org.unix.unistd_h.getpid());
    }
}
```

```
java Main.java
```

@oktaDev

@deepu105

Benchmark

Benchmark on OpenJDK 17

```
Full benchmark (average time, smaller is better)

Benchmark                    Mode  Cnt    Score    Error  Units

FFIBenchmark.JNI             avgt   40  49.182 ± 1.079  ns/op

FFIBenchmark.panamaDowncall  avgt   40  50.746 ± 0.702  ns/op

FFIBenchmark.panamaJExtract  avgt   40  48.838 ± 1.461  ns/op
```

https://github.com/deepu105/Java-FFI-benchmarks

So are we there yet?

Project panama current state

OpenJDK 17

- Can already work with languages that has C interop
  - like C/C++, Fortran, Rust, etc
- Performance on par with JNI
  - Hopefully this will be improved further
- Jextract makes is really easy to use native libs
- Memory safe and less brittle than JNI
- Native/off-heap memory access
- Documentation needs huge improvement
  - its an incubator feature so this is expected

Learn more

- https://foojay.io/today/project-panama-for-newbies-part-1/
- https://medium.com/@youngty1997/messing-around-with-project-panama-2019-ea-and-personal-thoughts-fd3445e9438b
- https://hg.openjdk.java.net/panama/dev/raw-file/4810a7de75cb/doc/panama_foreign.html#using-panama-foreign-jdk (some examples are outdated for current API)

Thank You

Deepu K Sasidharan

@deepu105 | deepu.tech

https://deepu.tech/tags#rust