Comparing Android Runtime with native: Fast Fourier Transform on Android

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May 2, 2017

Outline

Purpose of Thesis

- Why is this work important?

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- Where can it be used?

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- Why is this work important?
- Where can it be used?
- Who will benefit from it?

Research Question

Is there a significant performance difference between implementations of a Fast Fourier Transform (FFT) in native code, compiled by Clang, and Dalvik bytecode, compiled by Android Runtime, on Android?

1. Introduction
   - Purpose of Thesis
   - Research Question
2. Background
   - Android Development
   - Java Native Interface (JNI)
   - Discrete Fourier Transform (DFT)
   - Fast Fourier Transform (FFT)
   - Related Work
3. Method
   - Experiments
   - Measurements
   - Implementation
4. Results and Discussion
   - JNI
   - Libraries
   - NEON
   - `float` vs `double`
   - Garbage Collection
5. Conclusions

Android SDK

- Framework for developing applications
- Java
- Dalvik Virtual Machine

Android Runtime

- Replaced Dalvik Virtual Machine
- Ahead-Of-Time instead of Just-In-Time
- This allows for heavier optimizations

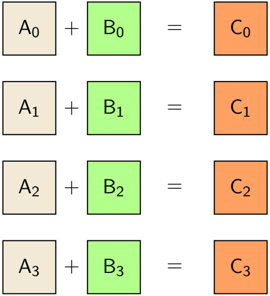
Android NDK

- Tools for building native applications
- Uses Clang and LLVM (as of 2017)
- Uses JNI to communicate between Java and Native

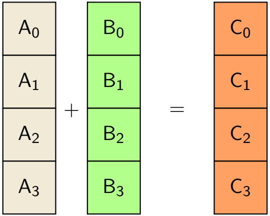
Java Native Interface (JNI)

- Bridge between JVM and binaries
- Run code compiled for a specific architecture from Java
- JVM communication

Vectorization



(a) Four separate instructions



(b) One instruction with SIMD

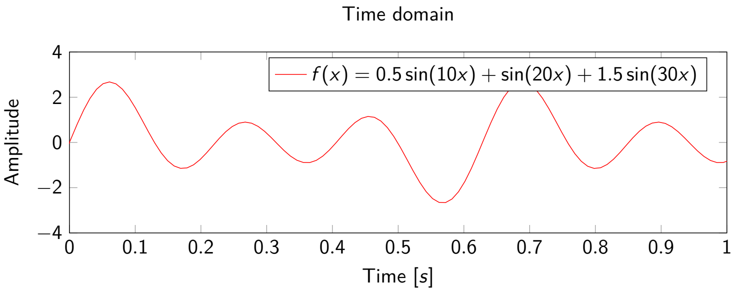
- SSE
- NEON

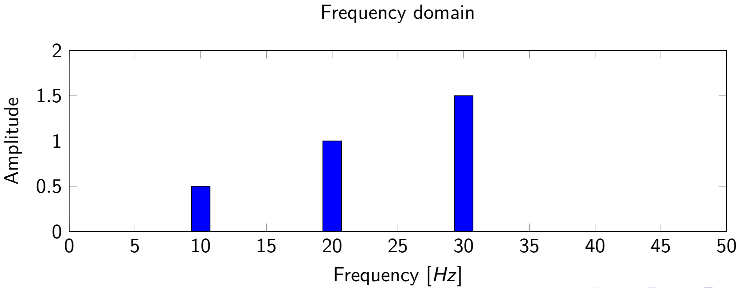
Discrete Fourier Transform (DFT)

- DFT: *Time* $\Rightarrow$ *Frequency*
- Decomposition of a signal
- Example uses:
  - Audio visualization
  - Speech recognition
  - Compression
  - Polynomial multiplication

$$X(k) = \sum_{n=0}^{N-1} x(n) \cdot e^{-j\frac{2\pi}{N}kn}, \quad k = 0, 1, 2, \ldots, N-1$$

Discrete Fourier Transform (DFT)





Fast Fourier Transform (FFT)

- Naive DFT, $O(N^2)$
- Cooley-Tukey FFT[1], $O(N \log N)$
- Trigonometric constants (twiddle factors)

[1]B. J. W. Cooley and J. W. Tukey, "An Algorithm for the Machine Calculation Complex Fourier Series", pp. 297–301, 1964.

Related Work

- S. Lee and J. W. Jeon, "Evaluating Performance of Android Platform Using Native C for Embedded Systems", *International Conference on Control, Automation and Systems*, pp. 1160–1163, 2010.

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- X. Chen and Z. Zong, "Android App Energy Efficiency: The Impact of Language, Runtime, Compiler, and Implementation", *2016 IEEE International Conferences on Big Data and Cloud Computing (BDCloud), Social Computing and Networking (SocialCom), Sustainable Computing and Communications (SustainCom)*, pp. 485–492, 2016.

Experiments

1. Cost of using JNI
2. Comparison of smaller FFT libraries
3. Native optimization with NEON
4. Using `float` and `double` data types

Measurements

- Nexus 6P used in all tests
- Time was measured in Java using `SystemClock.elapsedRealtimeNanos()`
- Data sizes varied between $2^4 - 2^{18}$
- 100 executions for each test, 95% confidence interval

Implementation

- **Java**
  - Princeton Recursive
  - Princeton Iterative
  - Columbia Iterative

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  - Princeton Iterative
  - Columbia Iterative
- **C++**
  - KISS (Keep It Simple Stupid) FFT
  - SSE Recursive FFT
  - SSE Iterative FFT

Implementation

- Benchmark application
- Java algorithms translated to C++
- Separate thread, one algorithm at a time
- Time measurements executed on a release build
- Memory measurements executed with an attached debugger

JNI

Block size	**No params**	**Vector**	**Convert**	**Columbia**
16	1.7922 ± 0.1392	1.9333 ± 0.1223	2.6052 ± 0.1004	4.1058 ± 0.3042
32	1.6983 ± 0.0220	2.8130 ± 1.7924	2.6006 ± 0.0370	3.9109 ± 0.0535
64	1.6755 ± 0.0149	1.6344 ± 0.1809	2.6630 ± 0.0425	3.9296 ± 0.0566
128	1.9604 ± 0.4978	1.2349 ± 0.1262	1.9375 ± 0.0843	3.0823 ± 0.0892
256	1.7292 ± 0.0694	1.3276 ± 0.2589	1.8141 ± 0.0276	3.0958 ± 0.0441
512	1.6916 ± 0.0110	1.2567 ± 0.1227	2.2818 ± 0.7011	3.1656 ± 0.0457
1024	2.0228 ± 0.5684	1.3167 ± 0.1341	6.3756 ± 8.4676	3.2896 ± 0.1396
2048	1.7218 ± 0.0288	1.5416 ± 0.1405	1.9099 ± 0.0898	3.4844 ± 0.1113
4096	1.1411 ± 0.0404	1.4010 ± 0.0788	2.0062 ± 0.1562	3.8562 ± 0.3197
8192	1.1105 ± 0.0078	1.4818 ± 0.0759	2.3671 ± 0.1897	3.8474 ± 0.4784
16384	1.1183 ± 0.0280	1.7308 ± 0.1043	2.5833 ± 0.1737	4.9724 ± 0.8955
32768	1.1162 ± 0.0084	2.2099 ± 0.1880	3.2062 ± 0.2029	5.3719 ± 0.2875
65536	1.7463 ± 1.2217	4.7474 ± 3.1960	4.3198 ± 0.2926	6.8136 ± 0.2499
131072	1.1027 ± 0.0141	2.6375 ± 0.1531	5.7004 ± 0.2681	9.6912 ± 1.4337
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Libraries

problems: Translating Java $\rightarrow$ C++ may not yield in comparable code. Compilers do different optimizations leading to different execution efficiency. This report is delimited to the chosen compilers and compiler versions.

NEON

float vs double

Garbage Collection

Conclusions

Conclusion 1

The overhead from JNI does not have a significant effect on performance.

Conclusion 2

Of the tested algorithms, choose Columbia Iterative.

Conclusion 3

Avoid allocating memory in the run-loop of a recurring task.

Conclusion 4

NEON optimization is significantly faster than non-optimized code for larger block sizes.

Questions?