Squawk: A Java™ Virtual Machine for Small (and Larger) Devices

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Overview

- Problems with Current Virtual Machines
- Squawk Principles
- The Squawk Virtual Machine
- Compilation Technology
- Some Results
- Applications

- Work in Progress

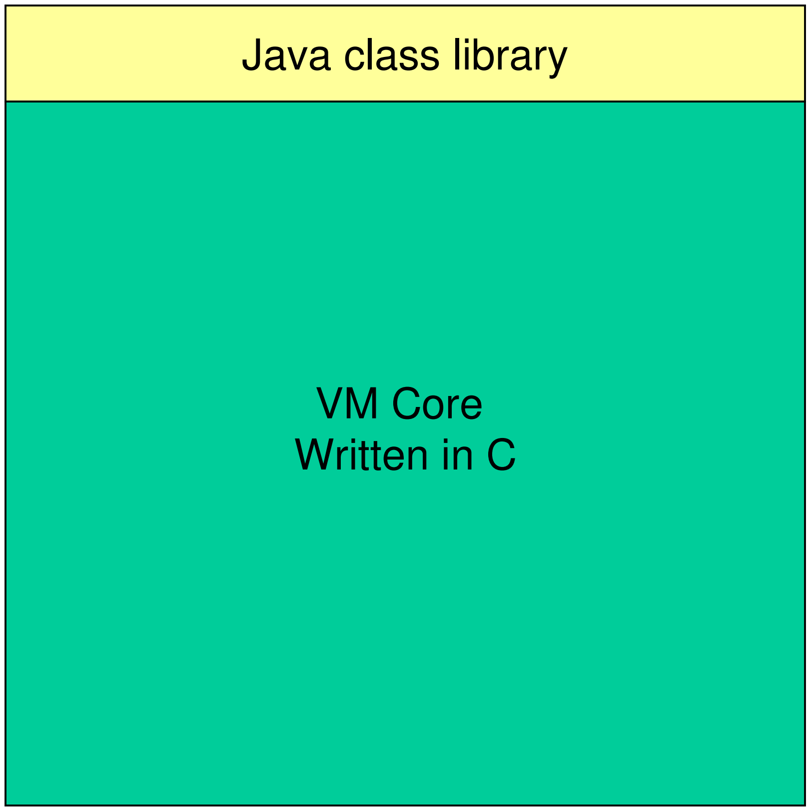
The Problem

- Most virtual machines are
  - Complex
  - Hard to understand
  - Hard to modify
  - Hard to maintain and
  - Hard to port

The Reason

- Architectural failures
  - Interaction between compiled, interpreted, and native code
  - Inadequate modularization
- C/C++ are not good languages for virtual machine construction
  - C is too low level a language
  - C has no provision for garbage collection

The Traditional Virtual Machine



Most of the VM is written
In C or C++.

There is little that these
languages have to offer
VM construction.

The Pointer Problem

There is no support in the C language for compacting garbage collectors.

C code

```
struct object *o = getObject();

gc();

x = o->someField;        **OOPS**!
```

Heap

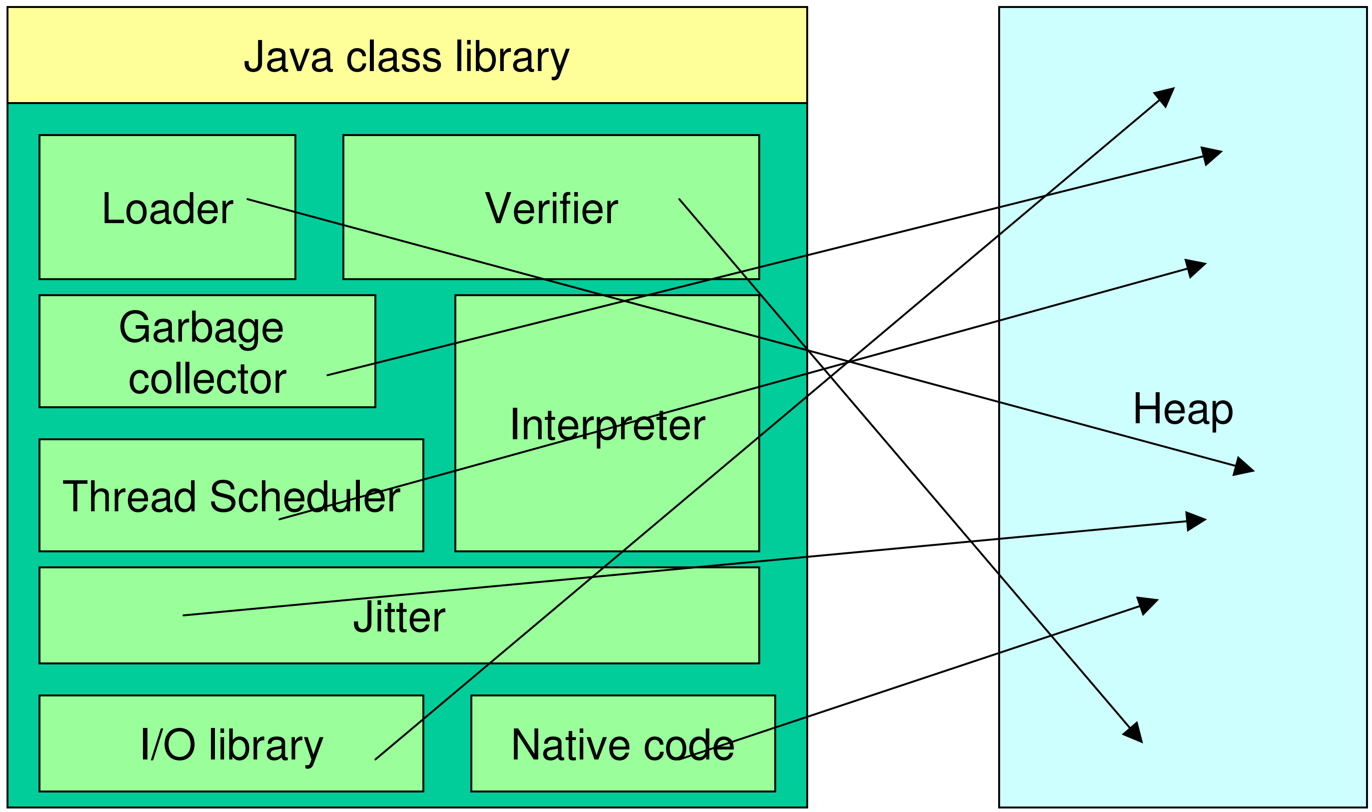
An Object

Calling the garbage collector moved the object and the local variable that pointed to it in the C code was not updated.

Conclusion: C and compacting garbage collectors do not work well together.

The Pointer Problem

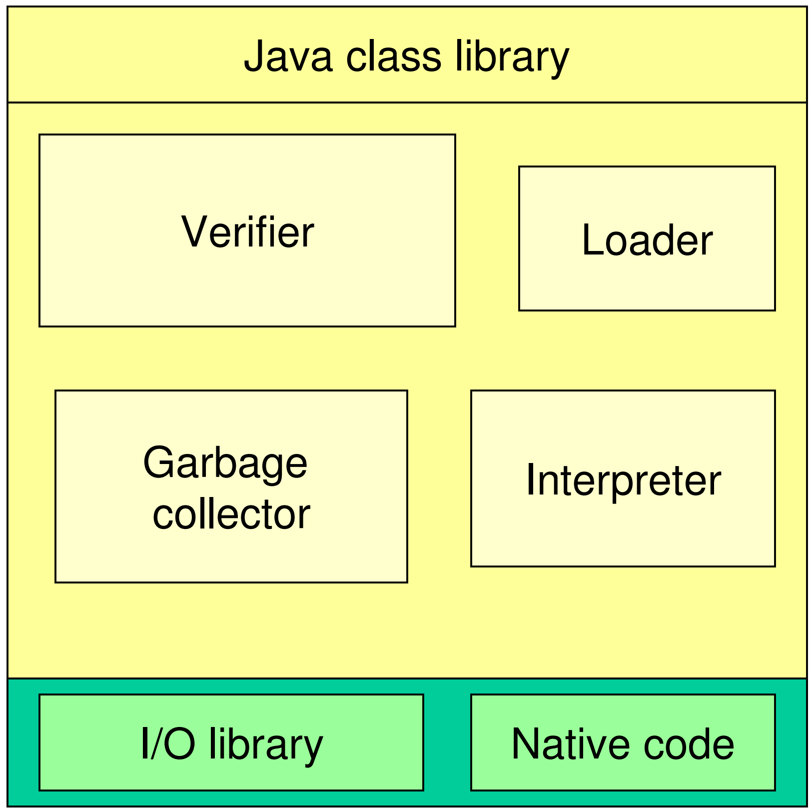
Somehow all these pointers must be updated by the garbage collector



Squawk Principles

- A Java VM all written in Java.
- A modular kit of parts.
- Simplicity is a goal.
- Performance is important.

Squawk for Java Card™



LCTES'03

Squawk for Java Card Requirements

- Next generation smart card
- 32-bit processor
- 8 Kb RAM
- 32 Kb non-volatile memory (NVM, EEPROM)
- 160 Kb ROM

Squawk Features

- CLDC compliant
  - Dynamic class loading
  - Verification
  - Exact garbage collection
  - CLDC 1.0 Java APIs
- Suites
  - Off-device preprocessing to package classes into a smaller representation
- Tri-partite memory
  - RAM->ROM->NVM
  - Chunky stacks (allocated in the RAM heap)

Squawk for Java Card Results (LCTES'03)

- Java->C interpreter, GC

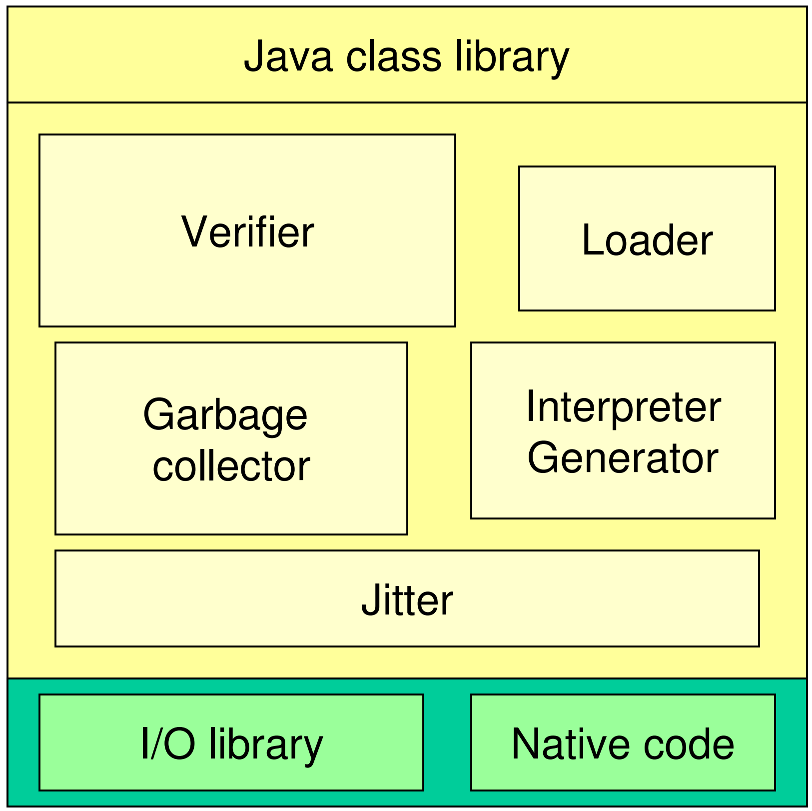
- Java CLDC compliant
  - Passes 4537 of 4628 TCK tests

- Static footprint
  - 25 Kb (interpreter + 2 GCs (RAM and NVM)) on x86
- Minimum runtime footprint in RAM
  - 520 bytes for the Java heap
  - 532 bytes for the native stack and data (x86)

- Suites
  - 38% the size of JAR files

- Runtime performance
  - ~KVM (84-107% on benchmarks)

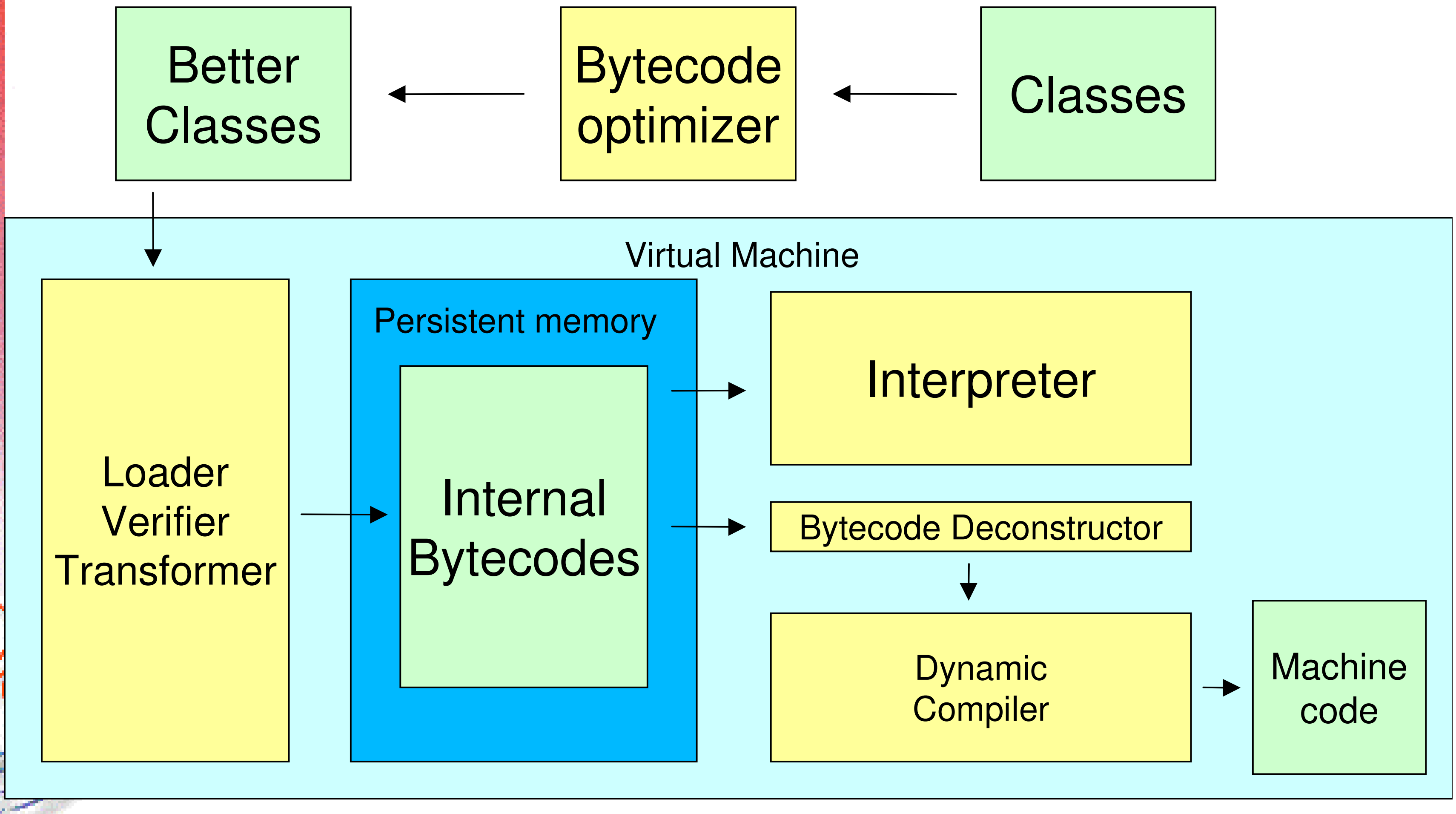
Squawk for Larger Systems



Squawk for Larger Systems - New Features

- Ahead-of-time bytecode optimization of system classes
- System built around a single compiler that can be used dynamically and ahead-of-time
    - AOT compilation of system classes
    - Dynamic compilation of user applications
- Isolates
    - Separate address spaces for multiple applications running on the one VM, with security guarantees
- Soft-real time support
- Everything written in Java

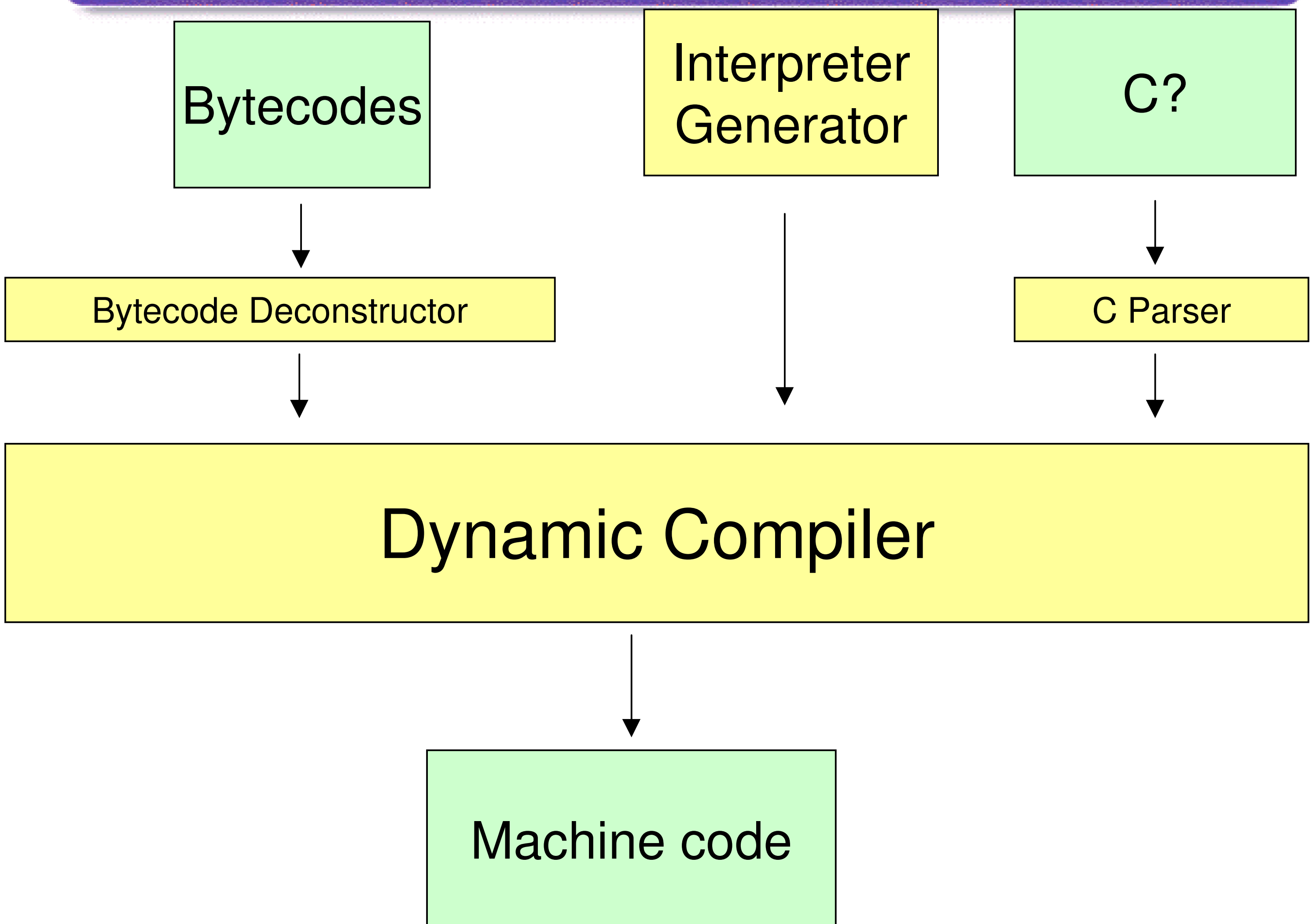
System Overview



Bytecode Optimization

- Produces standard Java class files
- Optimizations
  - Inlining
  - Constant propagation
  - Copy propagation
  - Constant folding
  - Dead-code elimination
  - …

The Dynamic Compiler



The Dynamic Compiler

- Needs to support a variety of target architectures
  - x86, ARM, PPC, SPARC
- Ease of porting
  - Target: 2 weeks
- Simple compiler
  - Fast, non-optimal, code generation
  - Small use of memory
  - Static optimizations supported by bytecode optimizer
  - => shadow stack representation

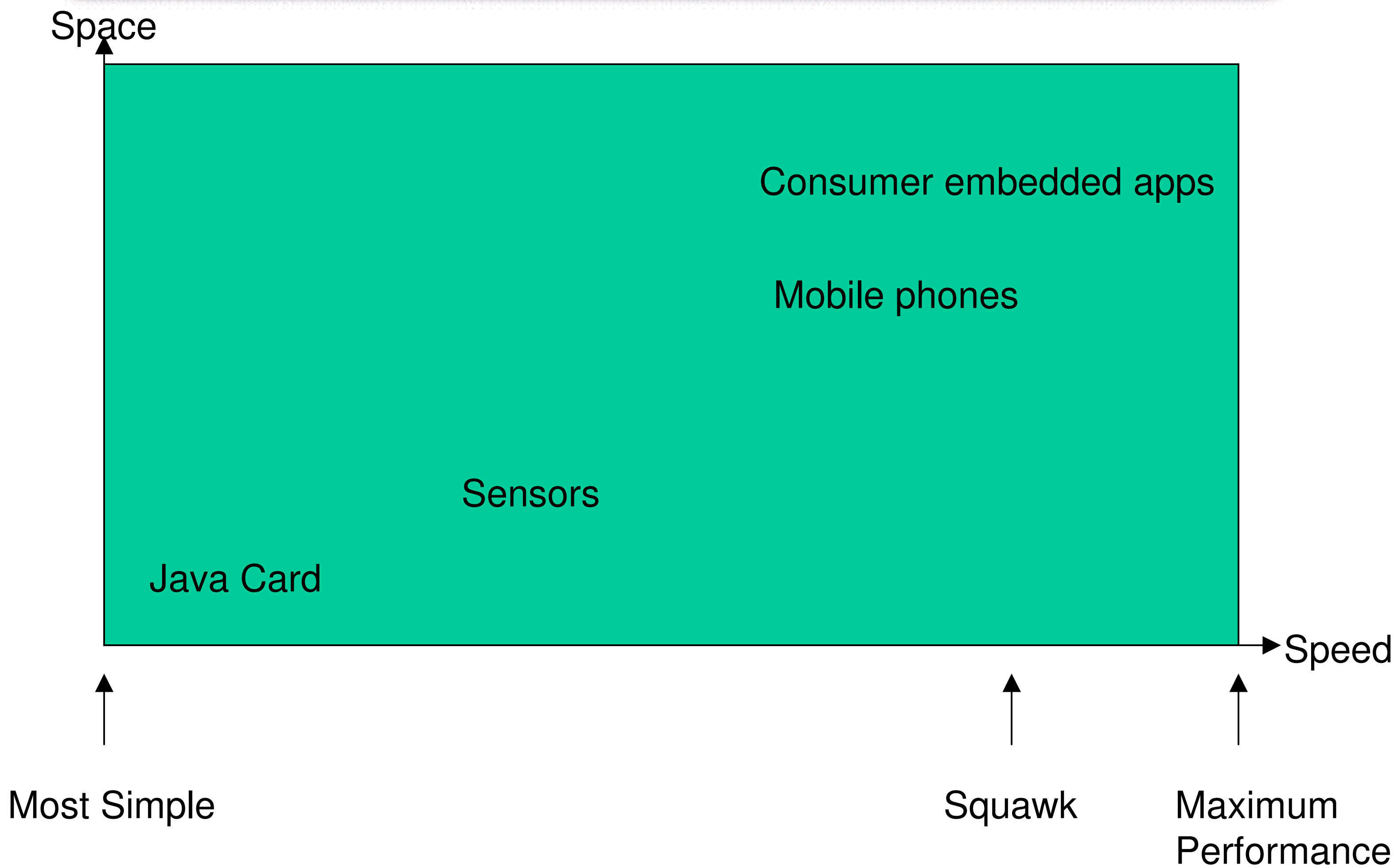
The Dynamic Compiler API - Example

```
public class Test implements Types {
    public static void main(String[] args) {

        Compiler c = Compilation.newCompiler();

        c.enter();
        Local x = c.parm(INT);      // x
        Local y = c.parm(INT);      // y
        c.result(INT);
            c.begin();
                c.load(x);          // x
                c.load(y);          // y
                c.add();            // x + y
                c.ret();            // return
            c.end();
        c.leave();

        c.compile();
        Linker linker = Compilation.newLinker(c);
        int entry = linker.link();
        int res = CSystem.icall(new Parm(entry).parm(1).parm(2));

        System.out.println("1 + 2 = "+res);
    }
}
```

Squawk - Applications

- Java Card
- Sensors
- Mobile phones
- Consumer embedded applications

Squawk – Application Requirements



Expected Results Squawk for Larger System

- Static footprint target
  - 50 Kb (interpreter + GC + jitter)
- Simple compiler target
  - 75% of gcc –O2

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