

Programming Languages for Building Trustworthy Systems

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Which Programming Language To Use?

- Safe versus unsafe, difficult choice?
 - **Safe** – Java, C#, Modula-3, ...
 - **Unsafe** – C, C++, assembler, ...
- But choice is really more complex
 - How much of a Java app is “safe”?
 - In a large system, there are many components
 - Should they all be safe?
 - Does it make sense to have 50% safe?
 - Platforms require extensibility
 - Economics may demand leveraging existing code
- Is the debate religious? Is one answer right?

Amdahl's Law Recast

- “Fraction of a system that is sequential determines maximum possible speedup”
similarly...
- “Fraction of a system that is unsafe determines that maximum possible trustworthiness”
- Suggests two research agendas:
 - Build systems with 0% unsafe code (Singularity)
 - Make existing C / C++ code safer (DieHard)
- We don't know the answer yet, but we do know what questions to ask...

0% Approach - Singularity (MSR)

- Jim Larus, Galen Hunt, and others
 - “Punctuated equilibrium” approach to evolution
- Re-architect and implement OS from scratch
- Design based on latest analysis techniques
- Design principles (partial list)
 - Complete process isolation
 - Type-checked process interaction (channels)
 - As much static analysis / checking as possible
 - Controlled dynamic extensibility (no dlls)
 - Type-safe at the bottom (all code, including OS)

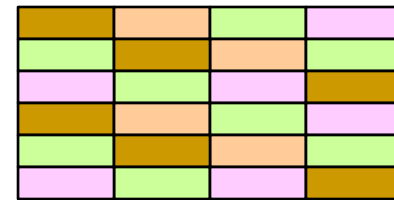
Making C and C++ Safer

- Gradualism approach
- Static analysis / safe subset of C or C++
 - Cyclone [Morrisett], SAFECode [Adve], etc.
- Runtime detection, fail fast
 - Jones & Kelly, CRED [Lam], CCured [Necula], SAFECode [Adve], SafeMem [Zhou], etc.
- Runtime toleration
 - Failure oblivious [Rinard] (unsound)
 - Rx [Zhou], Boundless Memory Blocks [Rinard], ECC, **DieHard**, Samurai, etc.

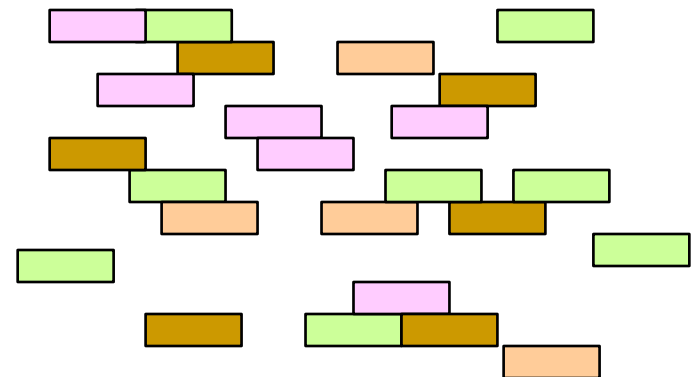
DieHard Allocator in a Nutshell

- Emery Berger and Ben Zorn
 - “Gradualism” approach
- Existing heaps are packed tightly to minimize space
 - Tight packing increases likelihood of corruption
 - Predictable layout is easier for attacker to exploit
- We randomize and overprovision the heap
 - Expansion factor determines how much empty space
 - Semantics are identical
- Easy to use – rejust relink app

Normal Heap



DieHard Heap



Summary

- Most applications and systems are...
 - Written in C and C++
 - Do not detect memory corruptions as they happen
 - Nevertheless, usually robust and reliable...
- Alternatives are available, but
 - More research is needed
 - Answering the question “rebuild from scratch” is expensive
 - Runtime technologies are promising

Additional Information

■ Web sites:

- ❑ Singularity: <http://research.microsoft.com/os/singularity/>
- ❑ Spec# : <http://research.microsoft.com/specsharp/>
- ❑ DieHard: <http://www.diehard-software.org/>

■ Publications

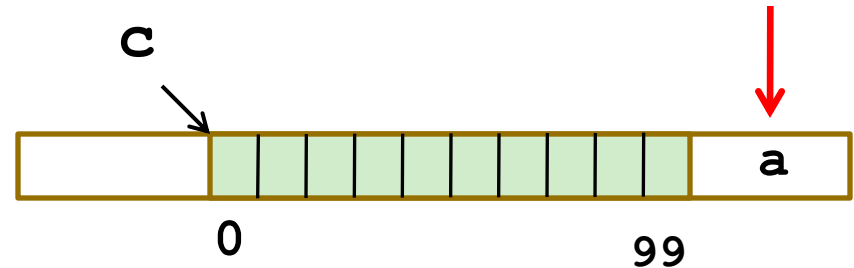
- ❑ Galen Hunt and James Larus, “**Singularity: Rethinking the Software Stack**”, *Operating Systems Review*, Vol. 41, Iss. 2, pp. 37-49, April 2007.
- ❑ Emery D. Berger and Benjamin G. Zorn, “**DieHard: Probabilistic Memory Safety for Unsafe Languages**”, *PLDI’06*.

Backup Slides

Avoiding Heap Memory Corruptions

■ Buffer overflow

```
char *c = malloc(100);  
c[101] = 'a';
```



■ Dangling reference

```
char *p1 = malloc(100);  
char *p2 = p1;
```

```
free(p1);  
p2[0] = 'x';
```

