Automatic Program Reoptimization Support in LLVM ORC JIT

by Sunho Kim

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  - Which is what this talk will be about

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- **Runtime profile guided optimization**
  - De-virtualization, instruction reordering, and other types of PGOs in ORC JIT
- **Scientific computing (CERN)**
  - Use high precision floating point for early iterations and use low precision floating point in later iterations for places that matter

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llvm-project / llvm / docs / HistoricalNotes / 2003-06-25-Reoptimizer1.txt

ddunbar [typo] An LLVM.

Code Blame 137 lines (105 loc) · 5.88 KB

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Wed Jun 25 15:13:51 CDT 2003

First-level instrumentation
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We use opt to do Bytecode-to-bytecode instrumentation. Look at
back-edges and insert llvm_first_trigger() function call which takes
no arguments and no return value. This instrumentation is designed to
be easy to remove, for instance by writing a NOP over the function
call instruction.

Keep count of every call to llvm_first_trigger(), and maintain
counters in a map indexed by return address. If the trigger count
exceeds a threshold, we identify a hot loop and perform second-level
instrumentation on the hot loop region (the instructions between the
target of the back-edge and the branch that causes the back-edge).  We
do not move code across basic-block boundaries.


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llvm_first_trigger() with a NOP.

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Quite different but has the same name :)

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Usual executable generation pipeline in LLVM

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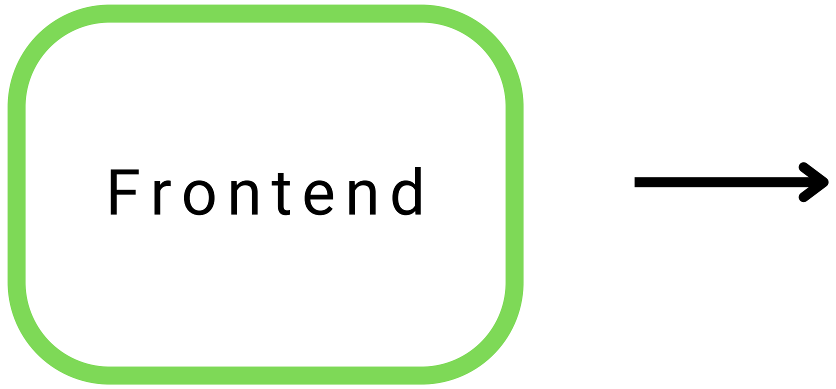

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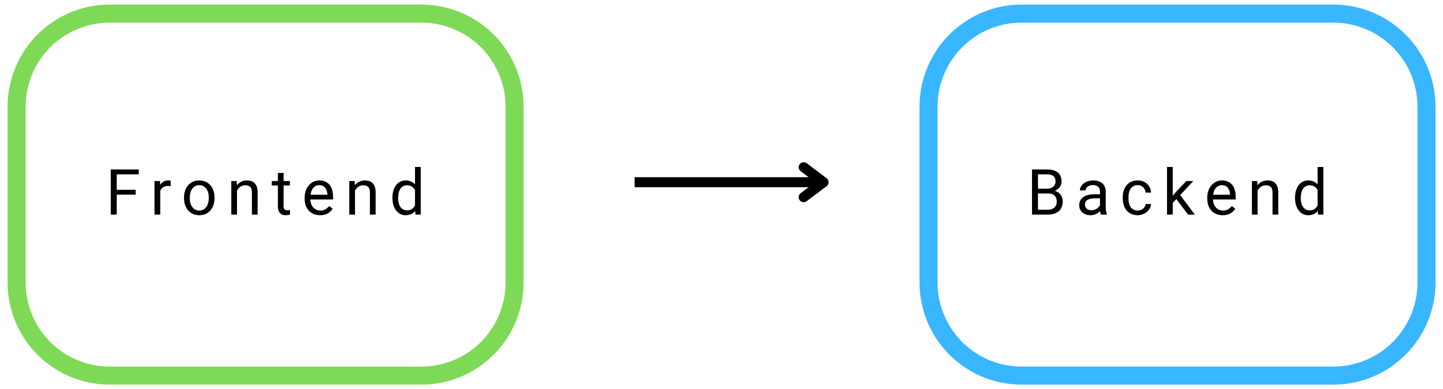

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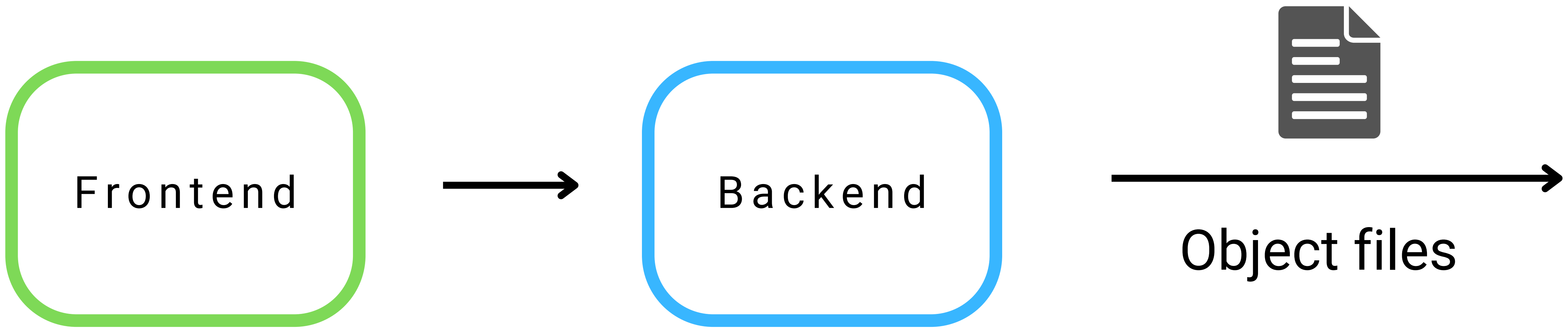

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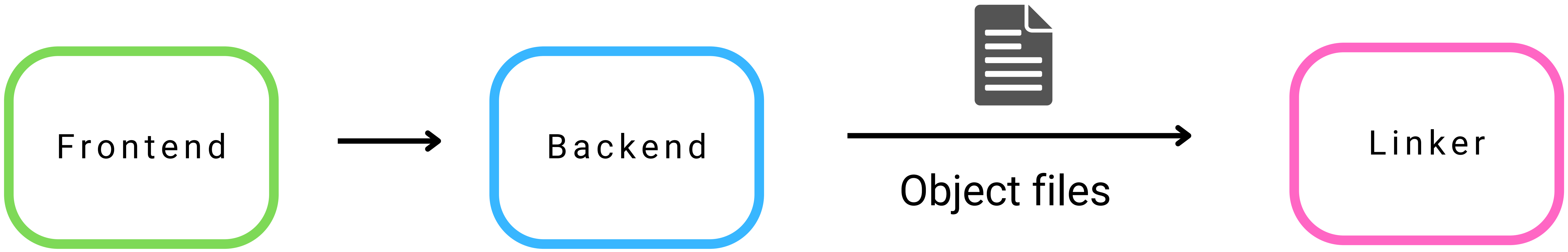

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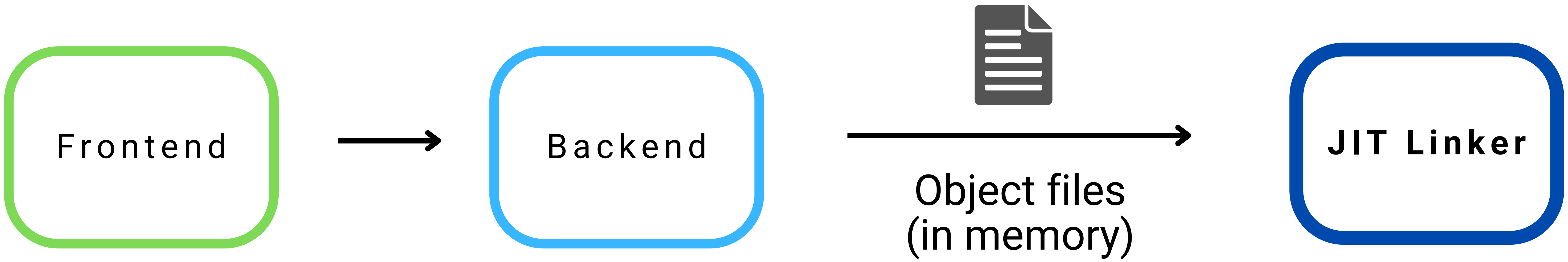

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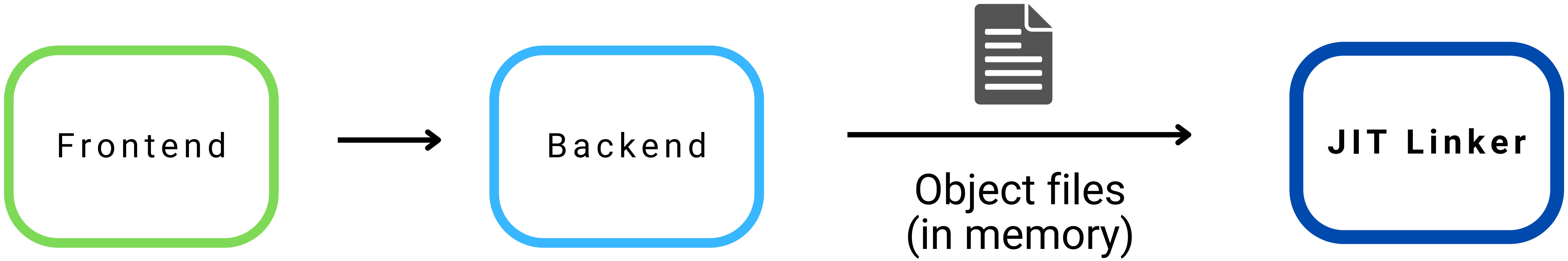

- Share a huge portion of pipeline with AOT
- Fewer breakage by LLVM internal code changes

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- **Multi-thread, remote process, speculative compilation ...**

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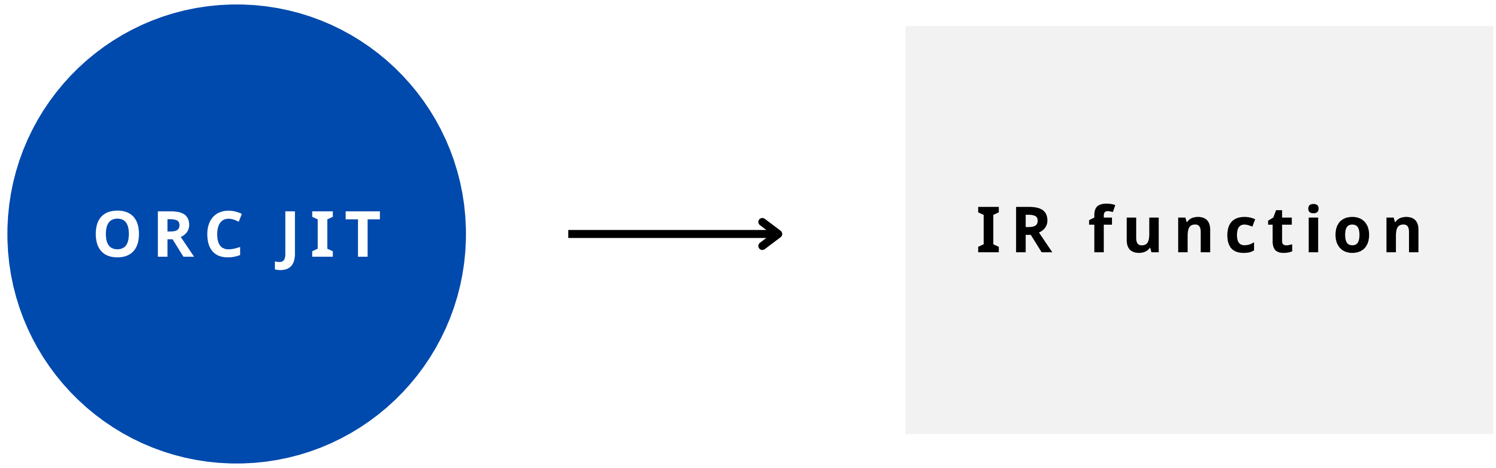

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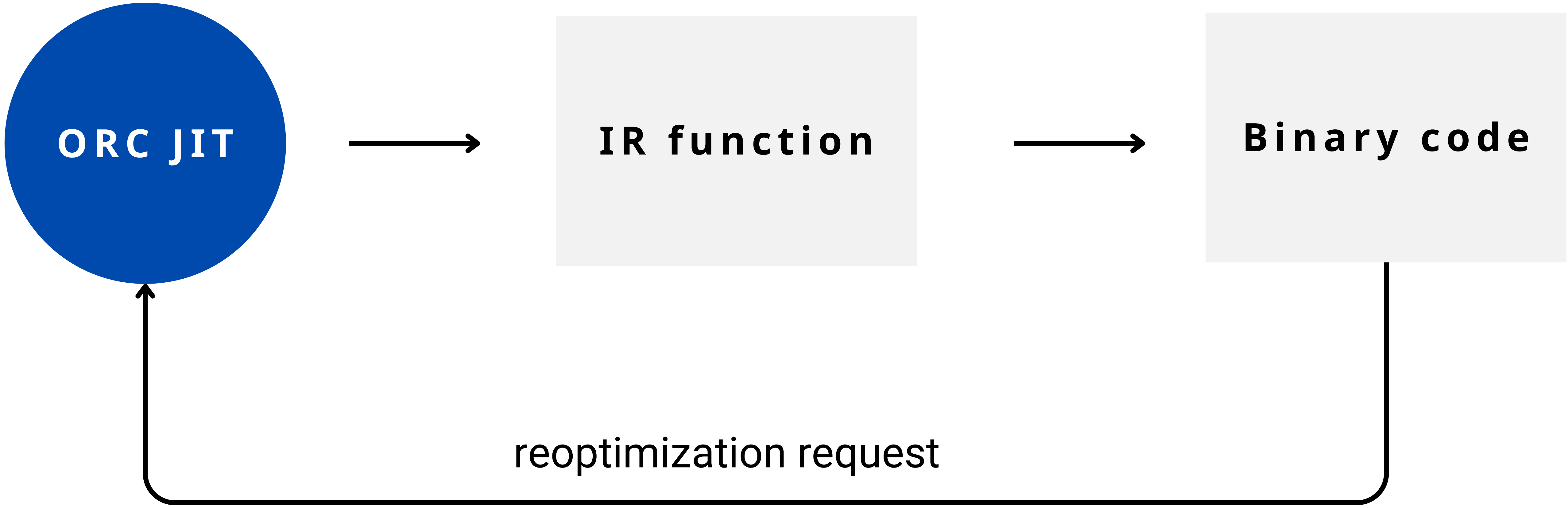

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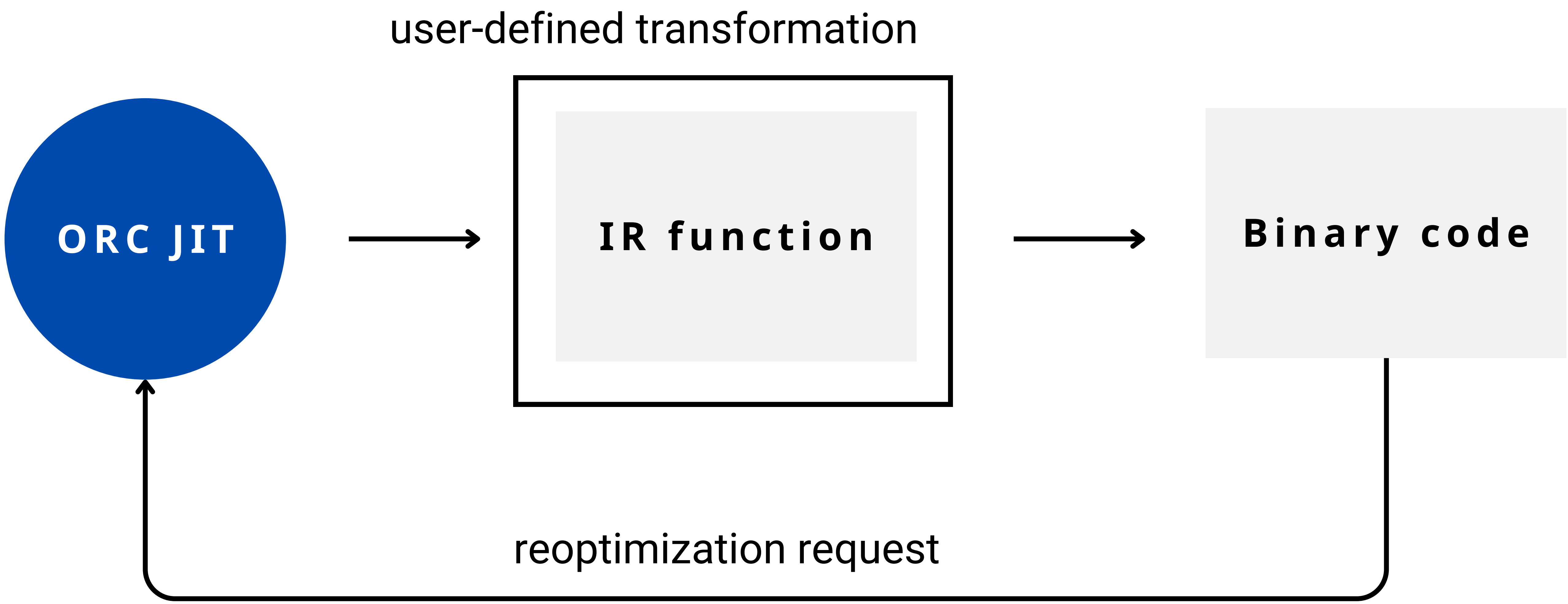

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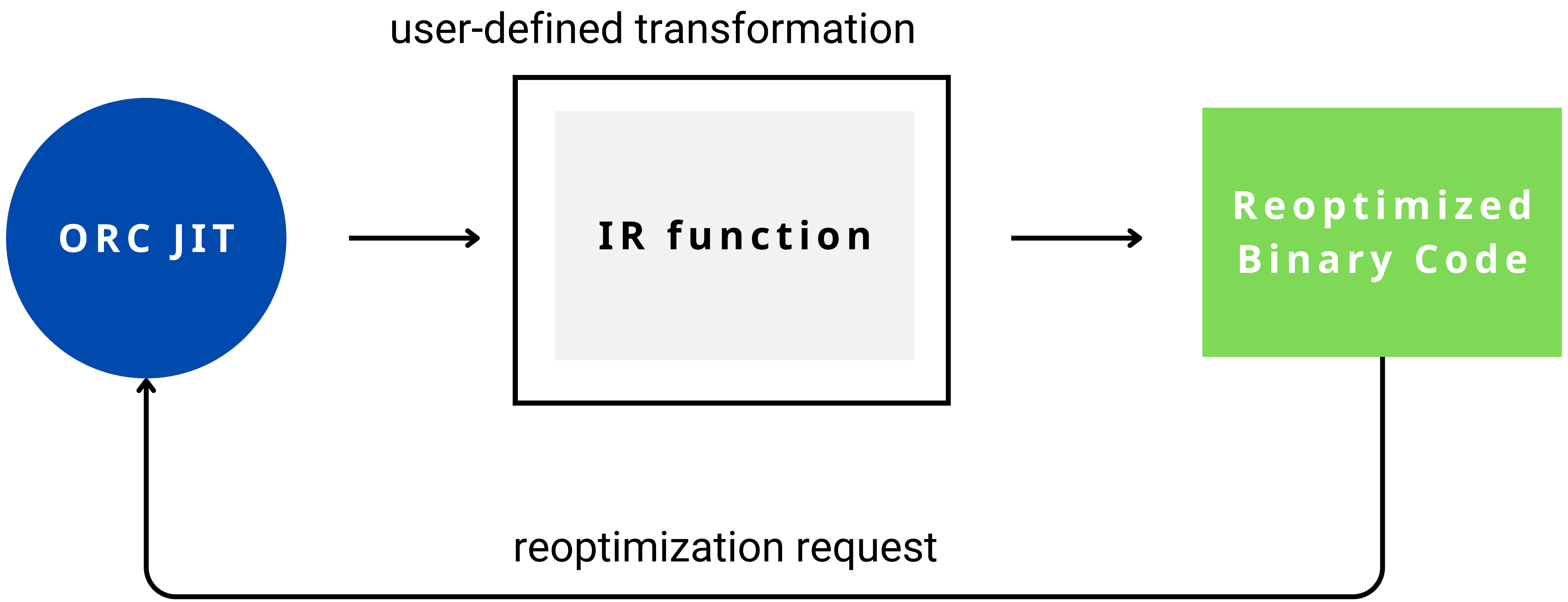

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```
static Error reoptimizeBasic(ReOptimizeLayer &Parent, ReOptMaterializationUnitID MUID,
    unsigned CurVerison, ResourceTrackerSP OldRT, ThreadSafeModule &TSM) {
  TSM.withModuleDo([&](llvm::Module &M) {
    // Do some re-optimization based on profile data
  });
  return Error::success();
}

auto ReOptLayer = std::make_unique<LLReOptimizeLayer>(ES, RSManager);
ReOptLayer->setReOptimizeFunc(reoptimizeBasic);
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  - Called to add instrumentation code to the “first version” of the functions.
  - Default is “reoptimizeIfCallFrequent” which requests re-optimization when call count is high.

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define di32 @hi() {
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  %cnt_is_20 = icmp eq i64 %0, 20
  %cnt_plus_one = add i64 %0, 1
  store i64 %cnt_plus_one, ptr @__orc_reopt_counter, align 8
  br i1 %cnt_is_20, label %reoptimize_request, label %return
reoptimize_request:
  call void @__orc_rt_reoptimize(i64 3, i32 0)
  br label %4
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Example: do -O2 optimization if function was called more than 10

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static Error reoptimizeToO2(ReOptimizeLayer &Parent, ReOptMaterializationUnitID MUID,
    unsigned CurVerison, ResourceTrackerSP OldRT, ThreadSafeModule &TSM) {
  TSM.withModuleDo([&](llvm::Module &M) {
    auto PassManager = buildPassManager();
    PassManager.run(M);
  });
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```

```
ReOptLayer->setReOptimizeFunc(reoptimizeToO2);
ReOptLayer->setAddProfilerFunc(reoptimizeIfCallFrequent);
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DEMO: CLANG-REPL WITH REOPT

- clang-repl is LLVM’s in-tree c++ interpreter based on ORC JIT API
- The code originally from CERN’s cling which has been used to analyze LHC data.

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    - indirect call to target or required offset is too large.
    - when platform prevents **writable and executable** memory for security reason.

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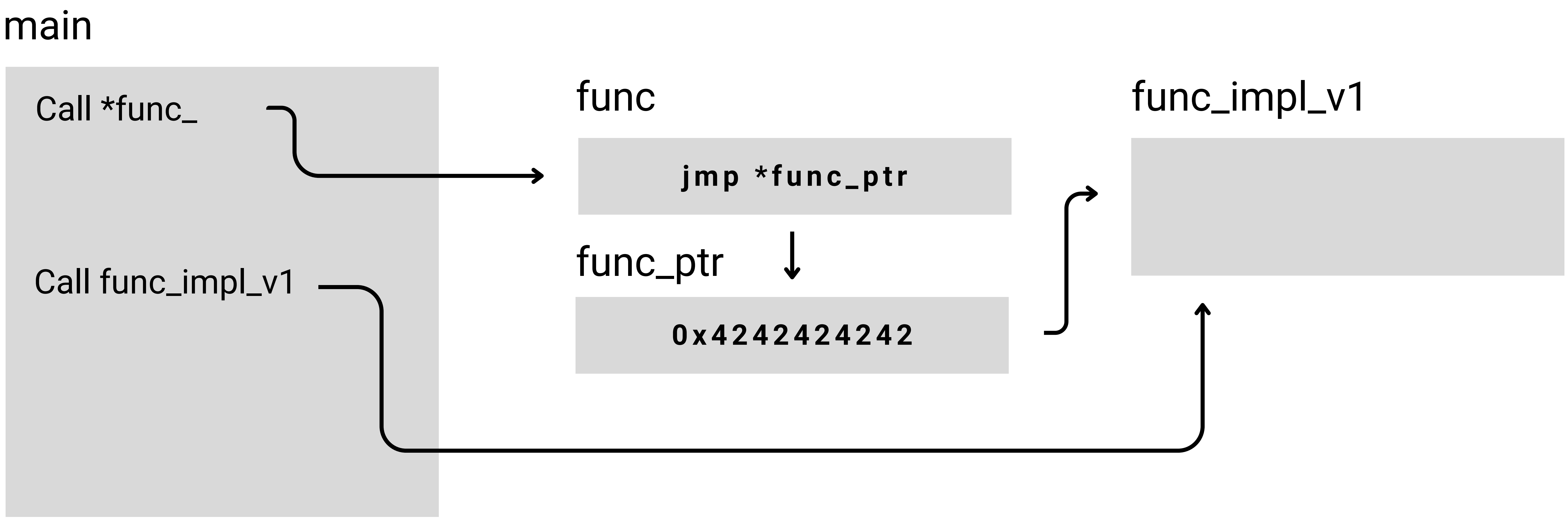
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Call func_impl_v1
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func_impl_v1

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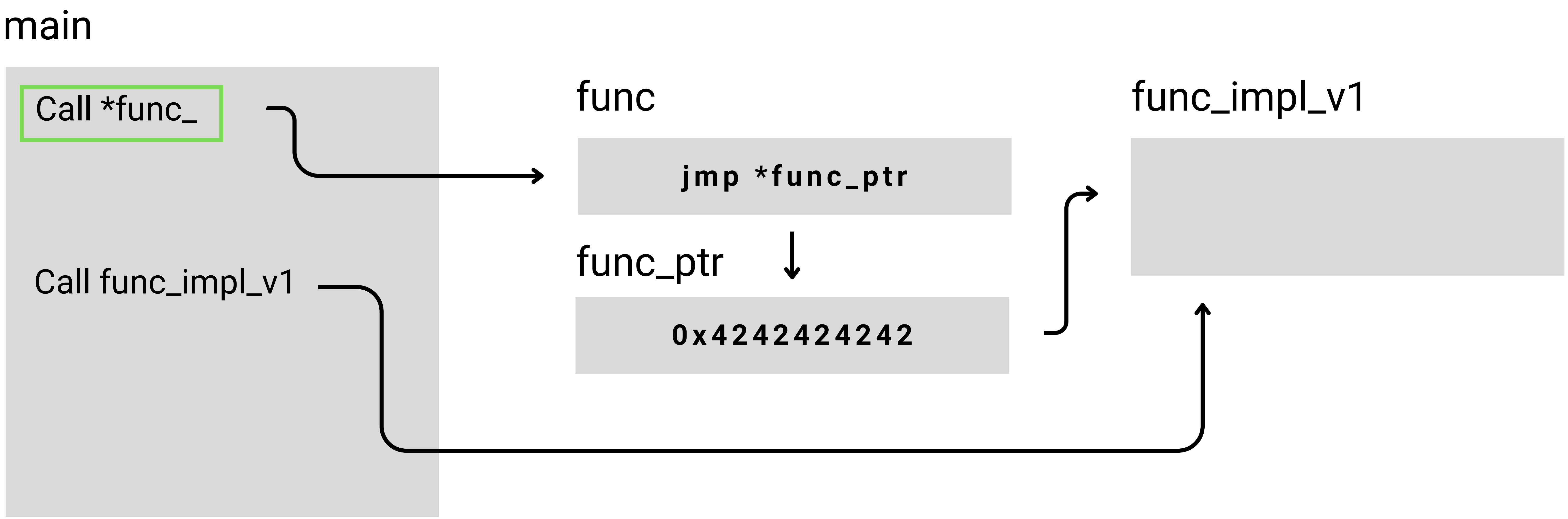

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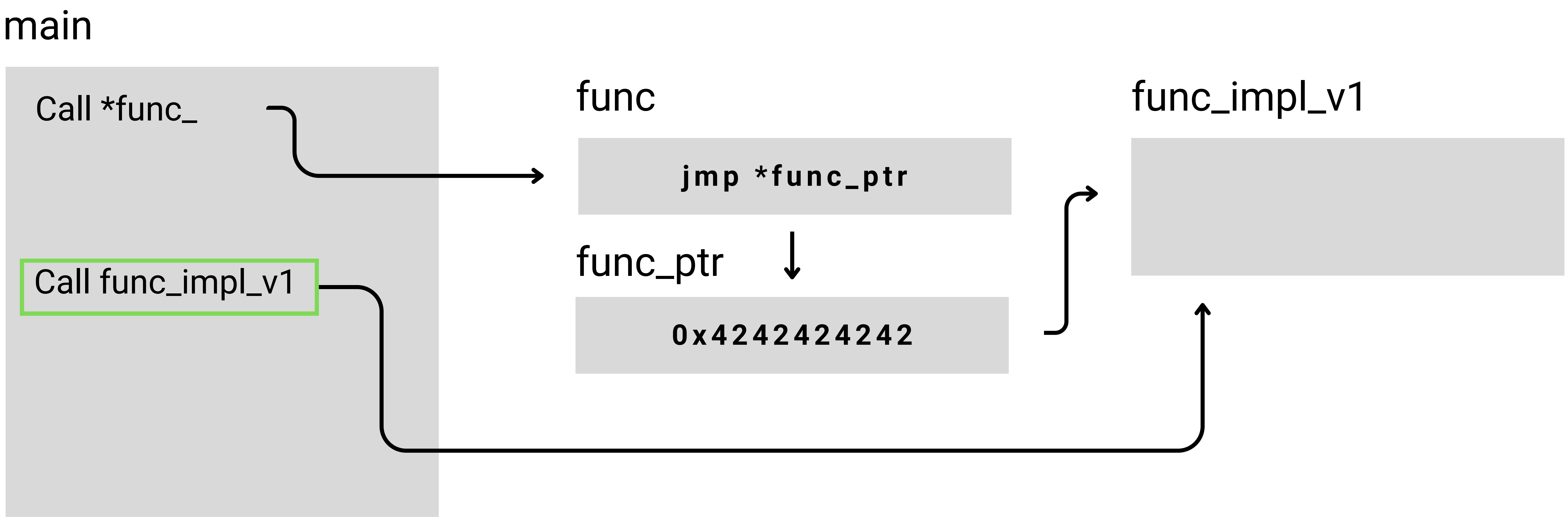

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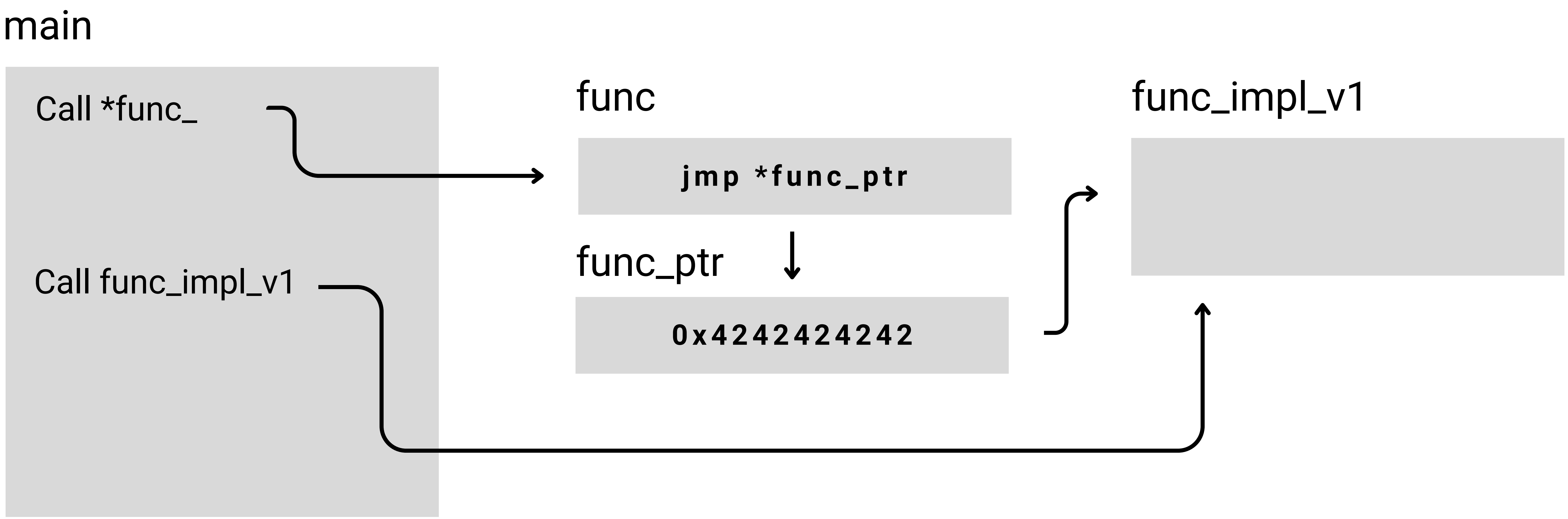
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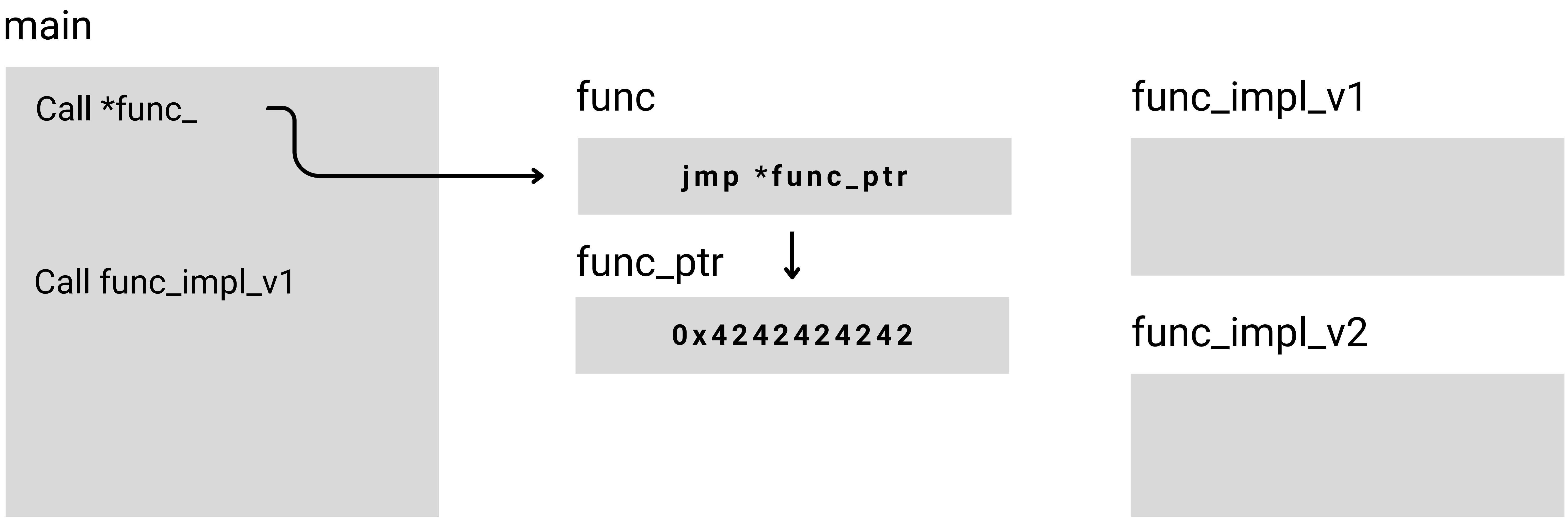

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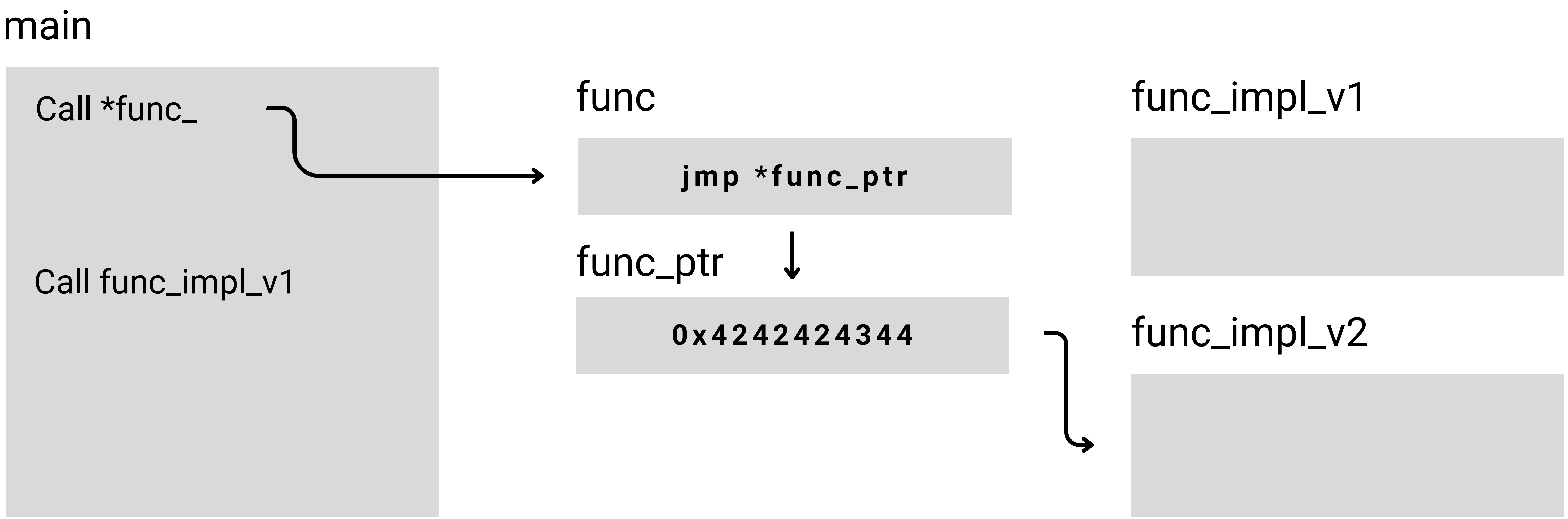
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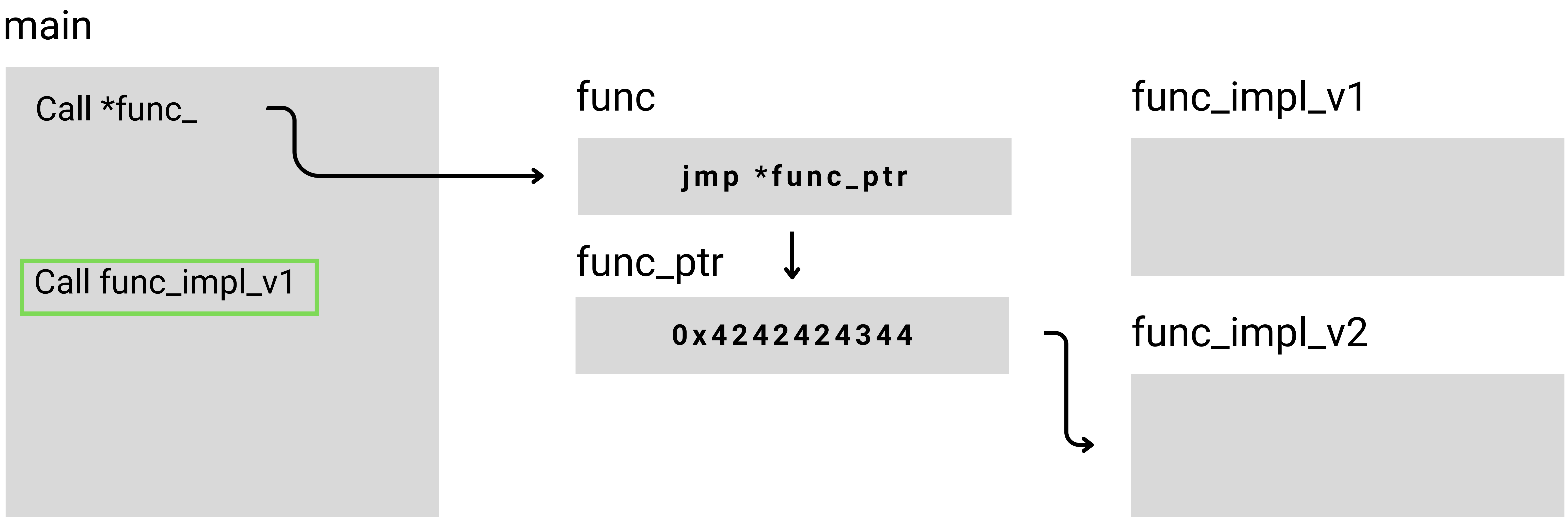
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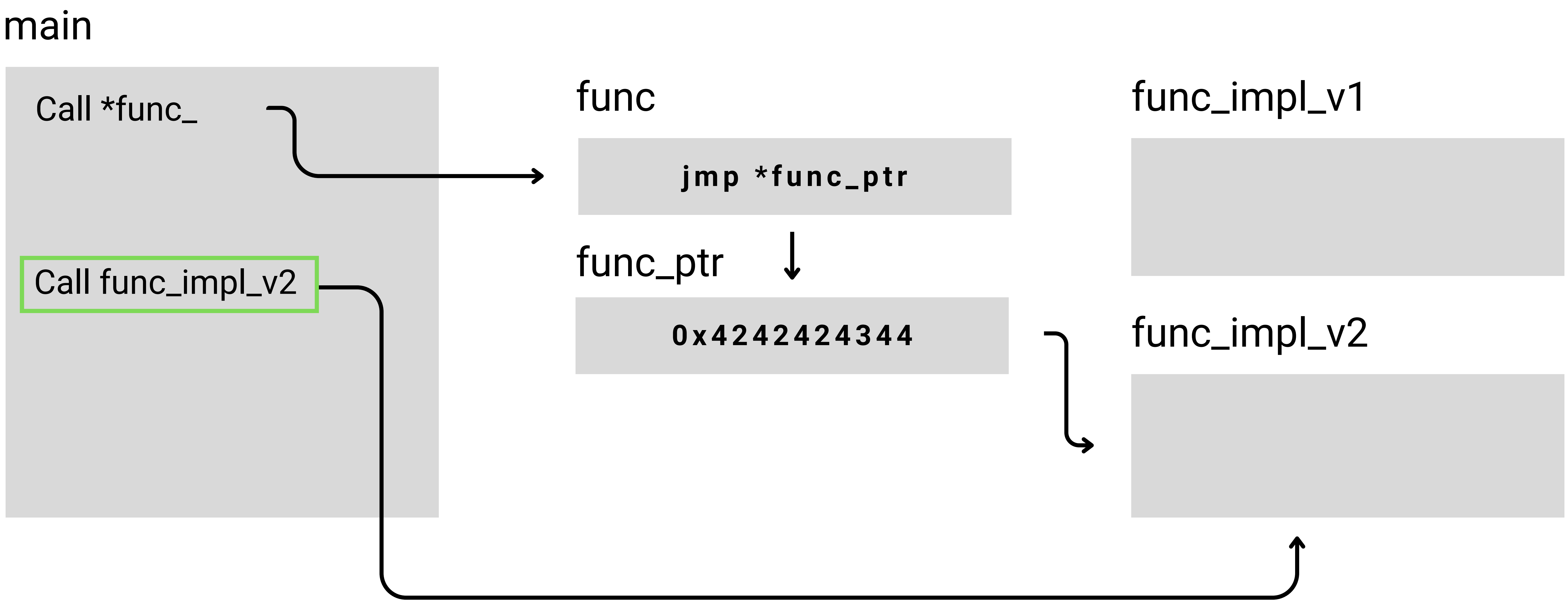
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- When calling virtual function, it **loads function address** from vtable of that classs

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public:
    virtual void meow() {}
};

int main() {
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  %2 = load ptr, ptr %1
  %3 = load ptr, ptr %2
  %4 = getelementptr inbounds ptr, ptr %3, i64 0
  %5 = load ptr, ptr %4, align 8
  call void %5
  ret i32 0
}
```

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  ret i32 0
}
```

ADVANCED USAGE OF REOPTIMIZATION API

Virtual method table

```cpp
class Animal {
public:
    virtual void meow() {}
};

int main() {
    Animal* animal;
    animal->meow();
}
```

```llvm
define i32 @main() {
  %1 = alloca ptr
  %2 = load ptr, ptr %1
  %3 = load ptr, ptr %2
  %4 = getelementptr inbounds ptr, ptr %3, i64 0
  %5 = load ptr, ptr %4, align 8
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```

indirect call

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  - Not just indirection cost but also lose opportunity for potential optimizations as values are not within the same basic block

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- If the function address is the known one, use the **inlined body**
- Otherwise **fall back** to indirect call

DEMO: CLANG-REPL WITH DEVIRTUALIZATION

- Showcasing the de-virtualization within clang-repl

ADVANCED USAGE OF REOPTIMIZATION API

JIT implementation

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JIT implementation

ORC JIT

JITted code

```
call %1
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JIT code buffer

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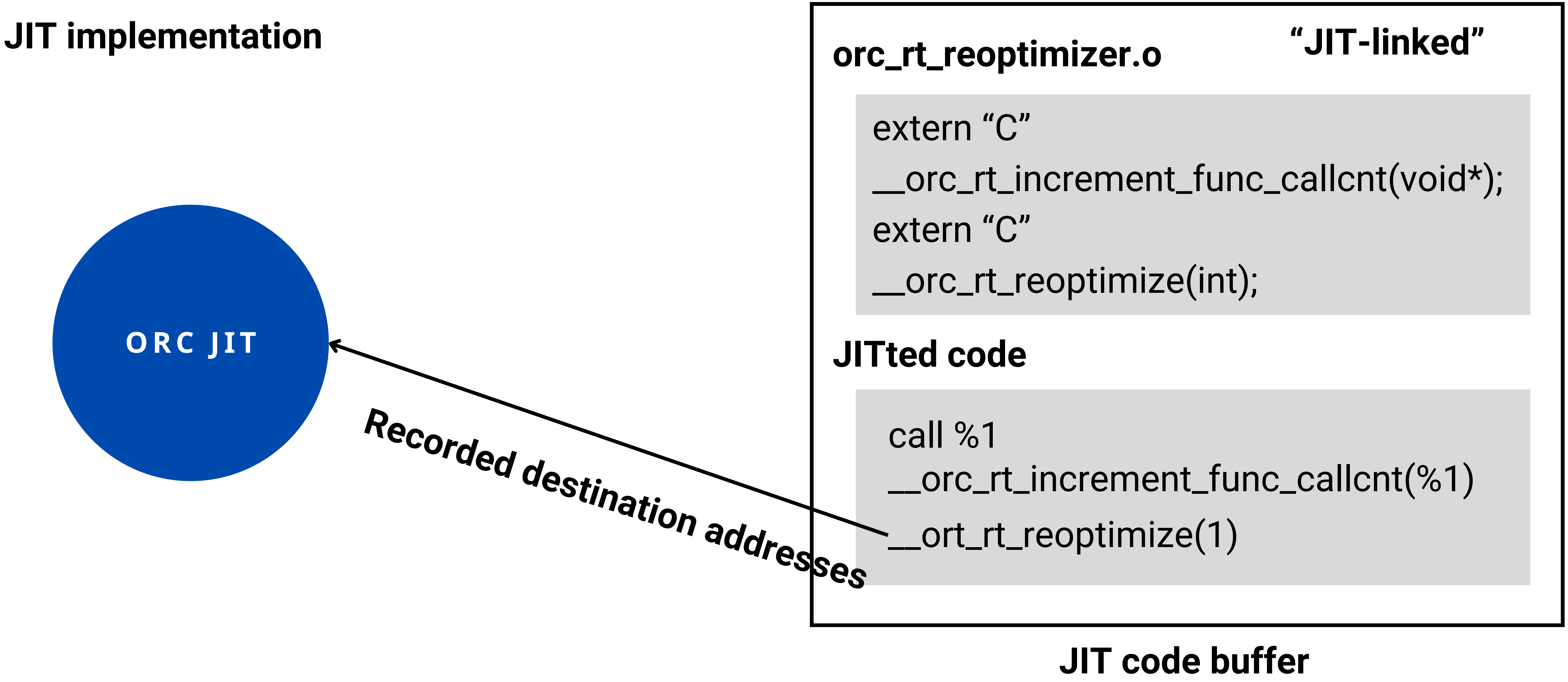
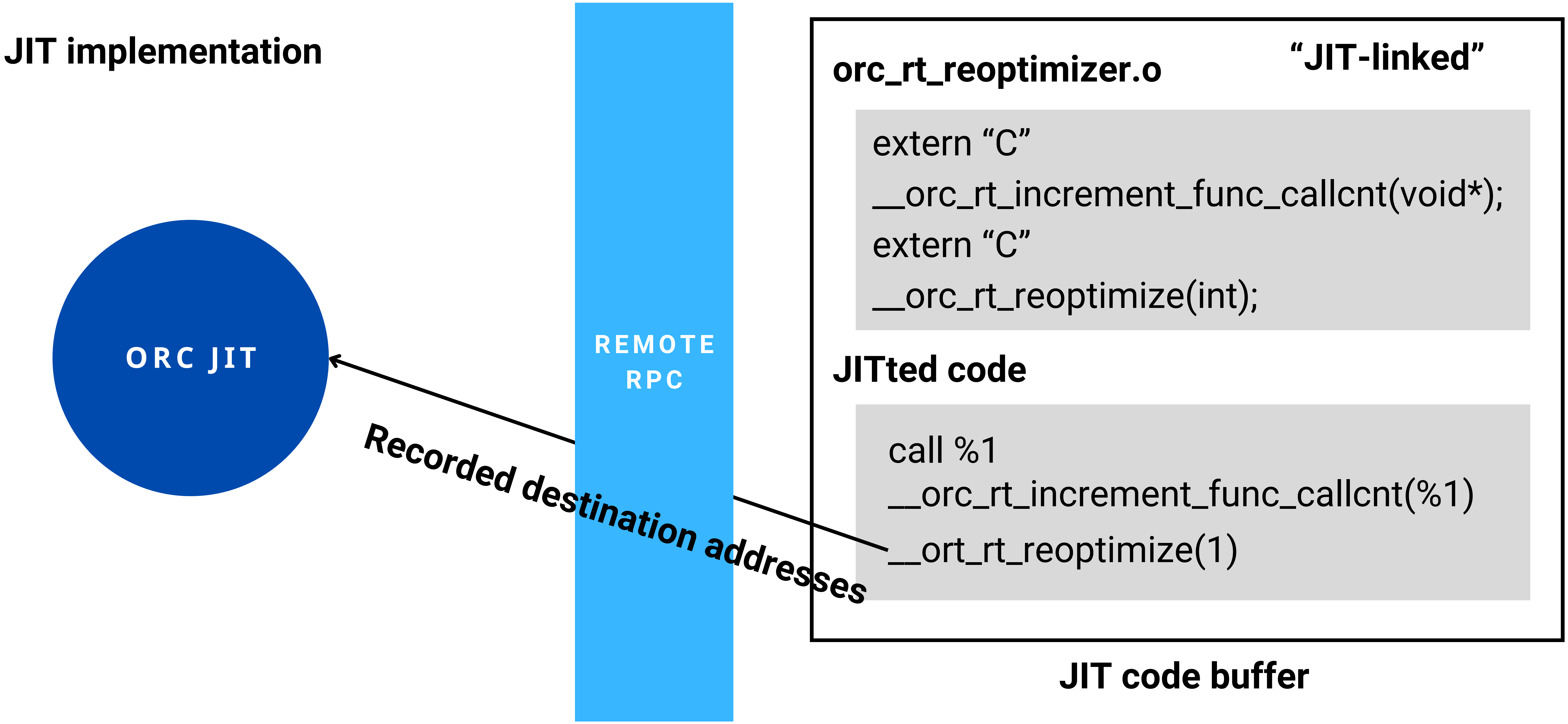


ADVANCED USAGE OF REOPTIMIZATION API



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  - but this introduces **compilation overhead** when module is large
  - O(n^2) function duplicates where n is number of functions

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  - **Penalty = cost for instrumentation + lost optimizations**
- **Generic JIT profile guided optimization framework**
  - Could we possibly overhaul LLVM’s existing PGO infrastructure in order to reuse it?

THANKS

Code used today is available at:
https://github.com/sunho/LLVM-JIT-REOPT-Example