Using Off-the-Shelf Exception Support Components in C++ Verification

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DIVINE – Verification of C++ Programs

DIVINE is a tool for testing and verification of C/C++ programs

- memory safety, assertion safety, parallelism errors
- easy error injection
- full support for C and C++, partial support for POSIX
- using clang/LLVM compiler infrastructure

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Contribution of this Work

- full support for C++ exceptions
- with minimal changes to the verification core of DIVINE
- re-using existing implementation of exception matching in the C++ runtime

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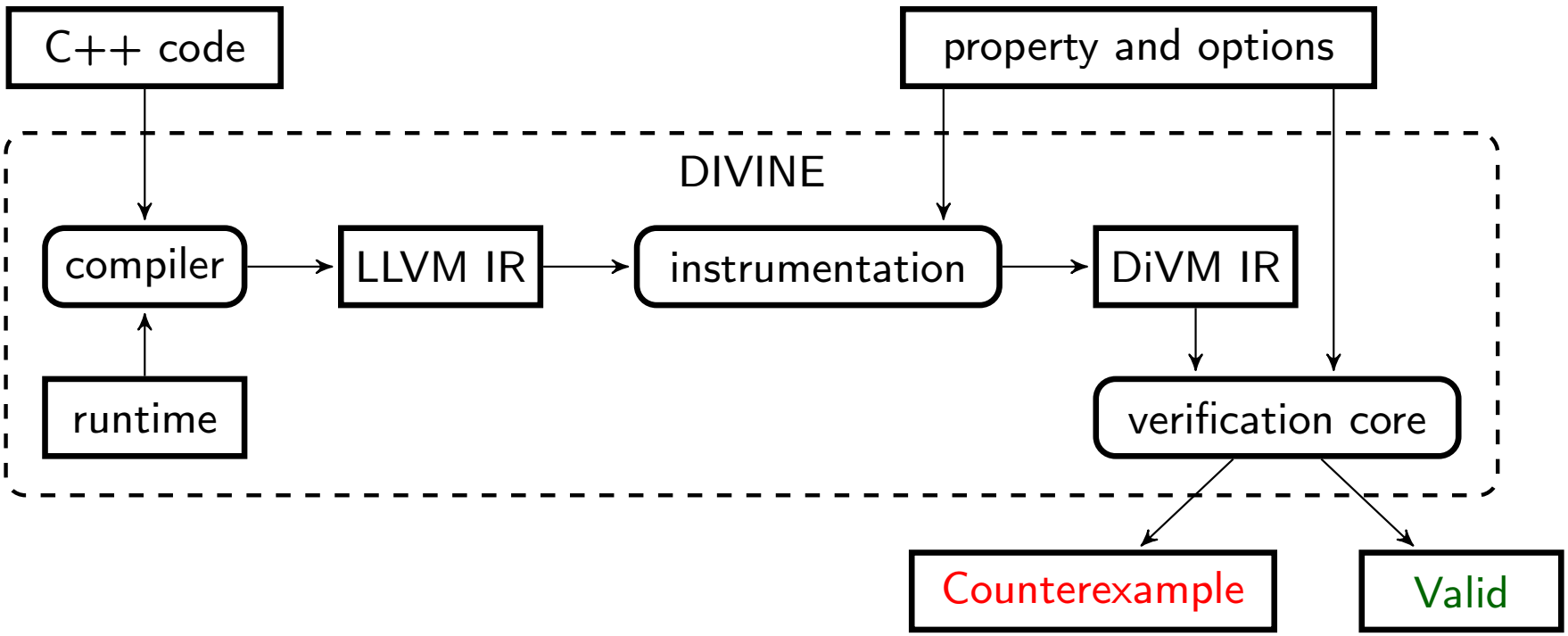

Motivation

C++ exceptions

- ubiquitous in real-world C++
- disabling exceptions can change behaviour (`new`)
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- using LLVM and clang helps a lot for C/C++ support
- DIVINE also re-uses C and C++ standard libraries
- more precise verification then with re-implementation of C++ support

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- more precise verification then with re-implementation of C++ support

- exceptions support is complex
- re-implementation would risk imprecisions, would be large, or require changes to the verification core

How Exceptions Work

```
1  X::~X() { }
2  void g() {
3    throw std::exception();
4  }
5  void f() {
6    X x;
7    g();
8  }
9
10 int main() {
11   try {
12     f();   <-------------------------
13   } catch ( ... ) {
14     /* ... */
15   }
16 }
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main:12

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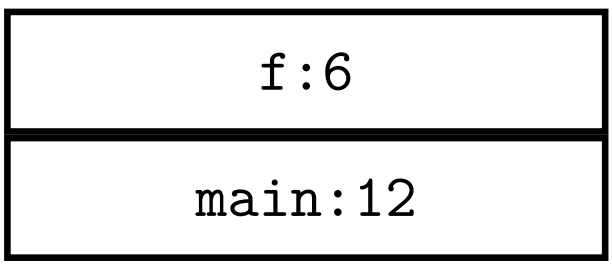

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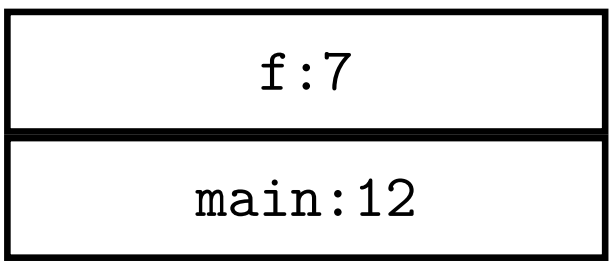

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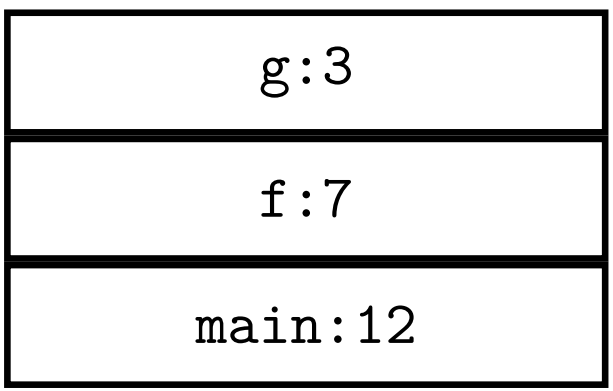

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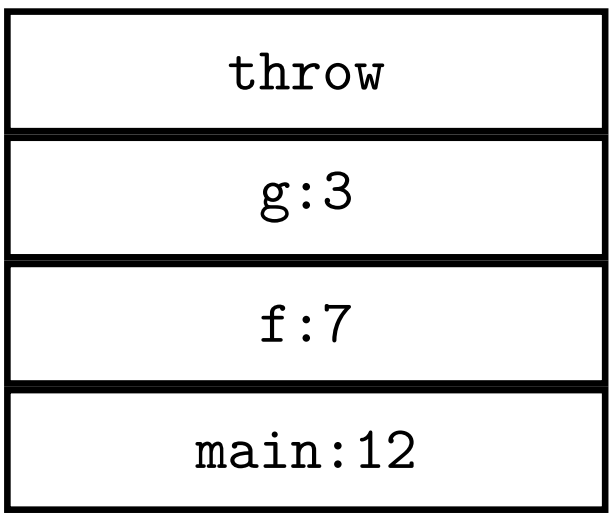

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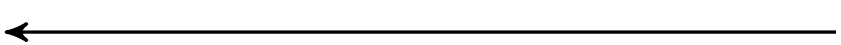

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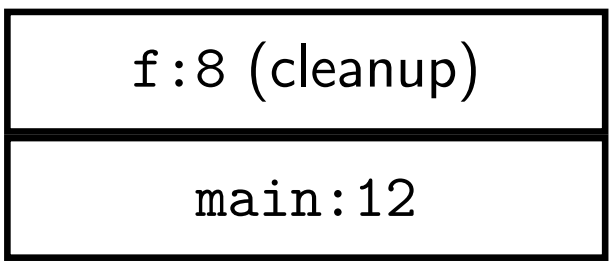

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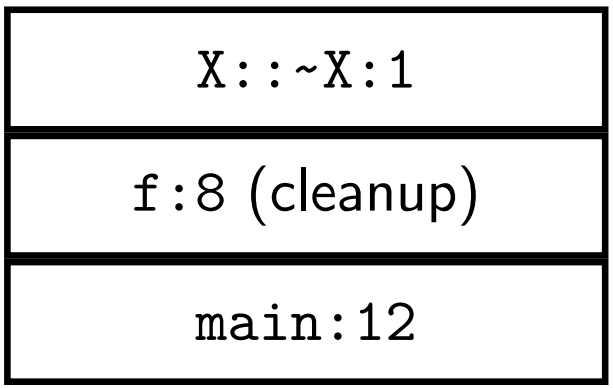

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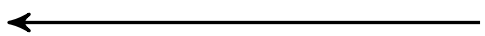
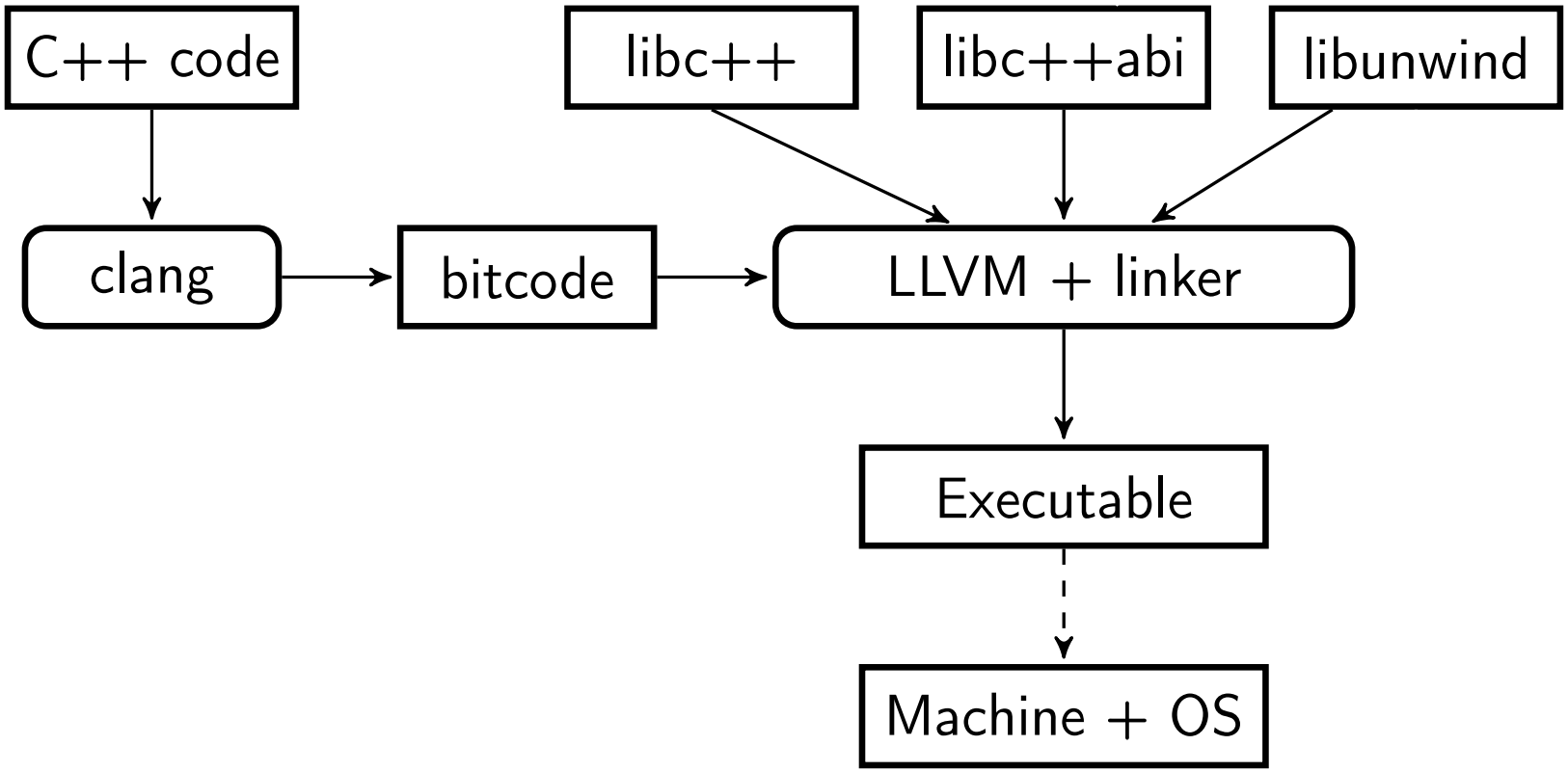


main:14

Running C++ Program



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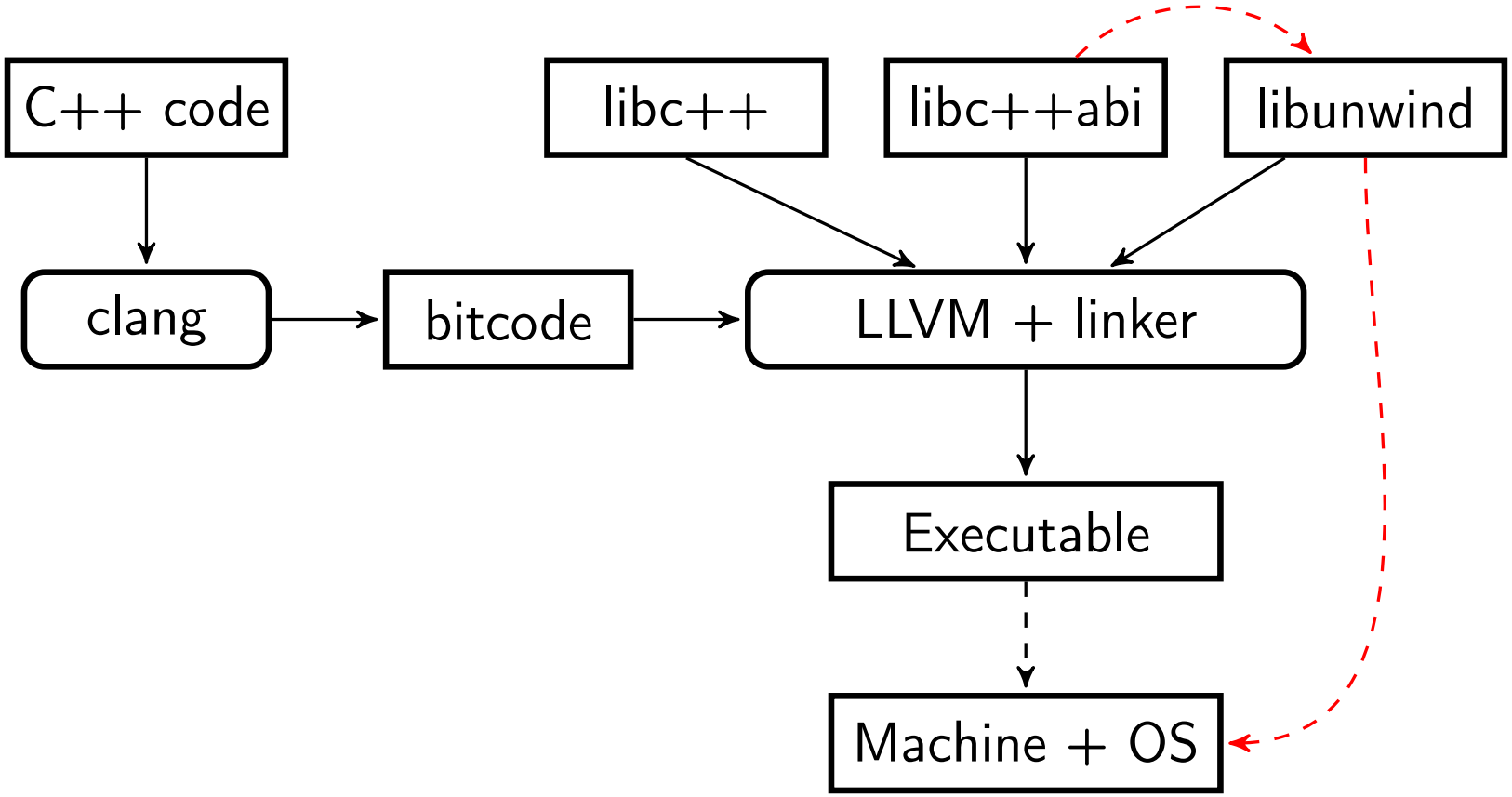

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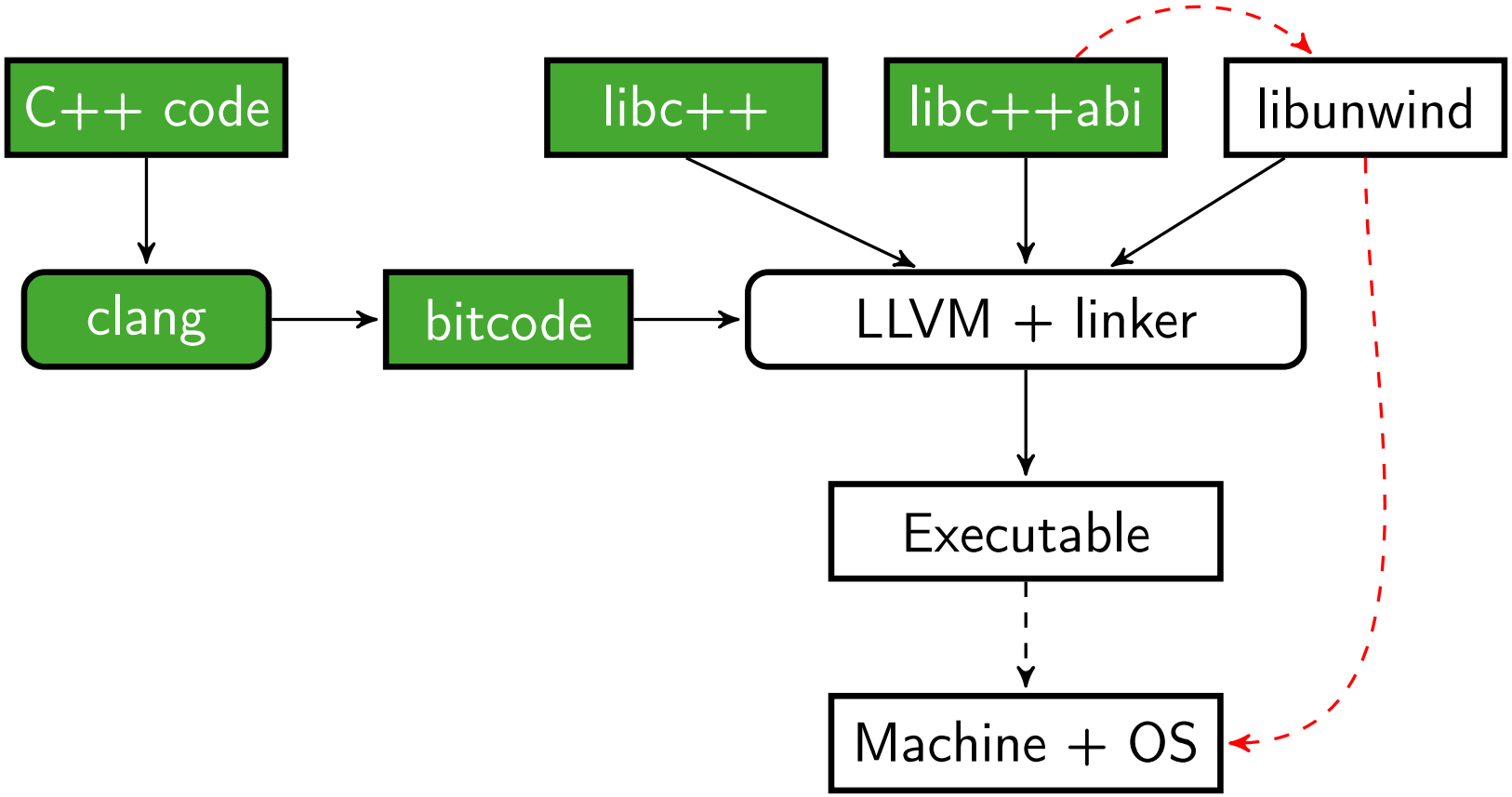

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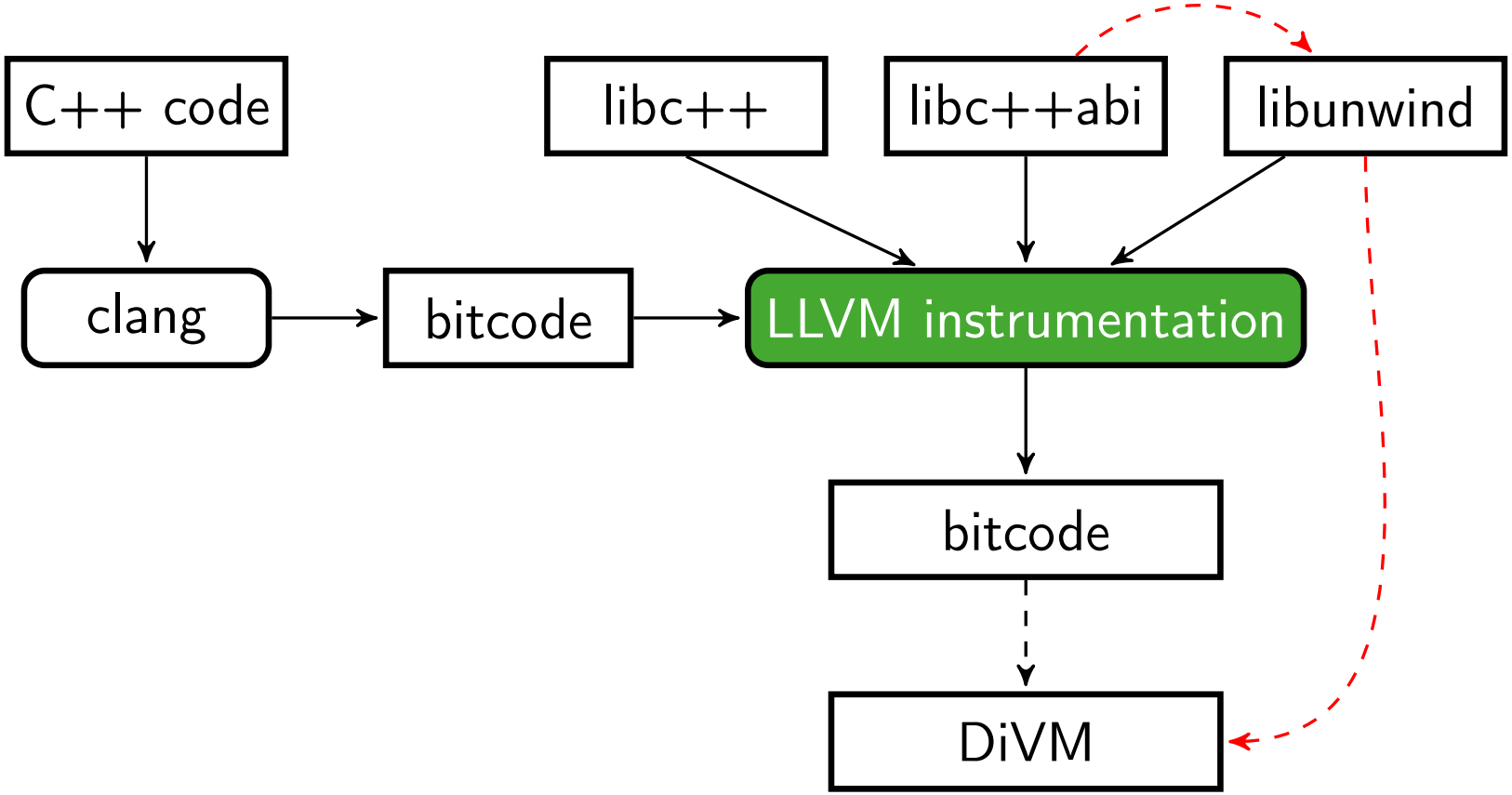
- the runtime library depends on the unwinder which depend on the machine and OS
- green components are re-used in DIVINE

Analyzing C++ Program with DIVINE



DIVINE/DiVM-specific components

- LLVM-based preprocessing

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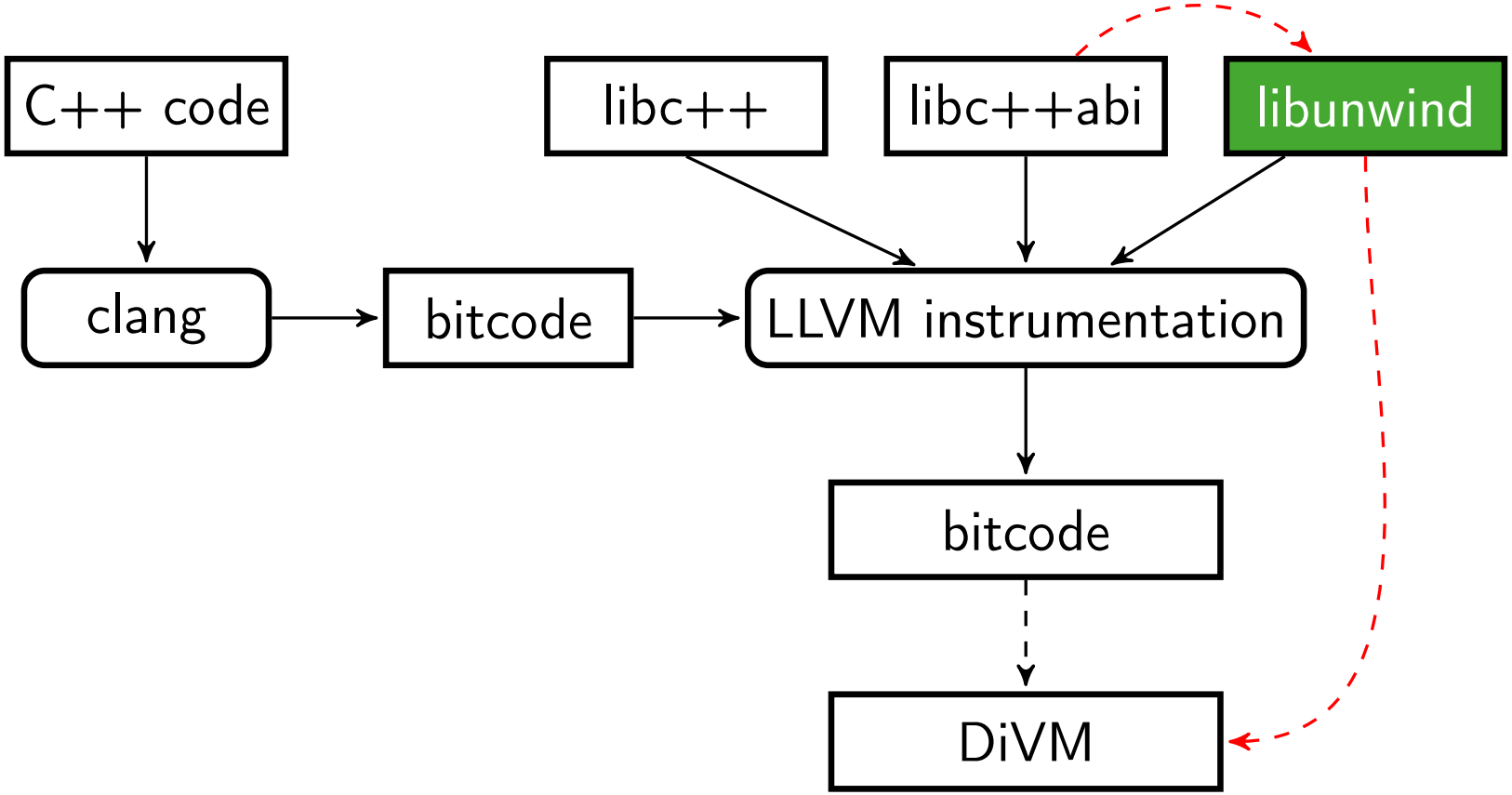

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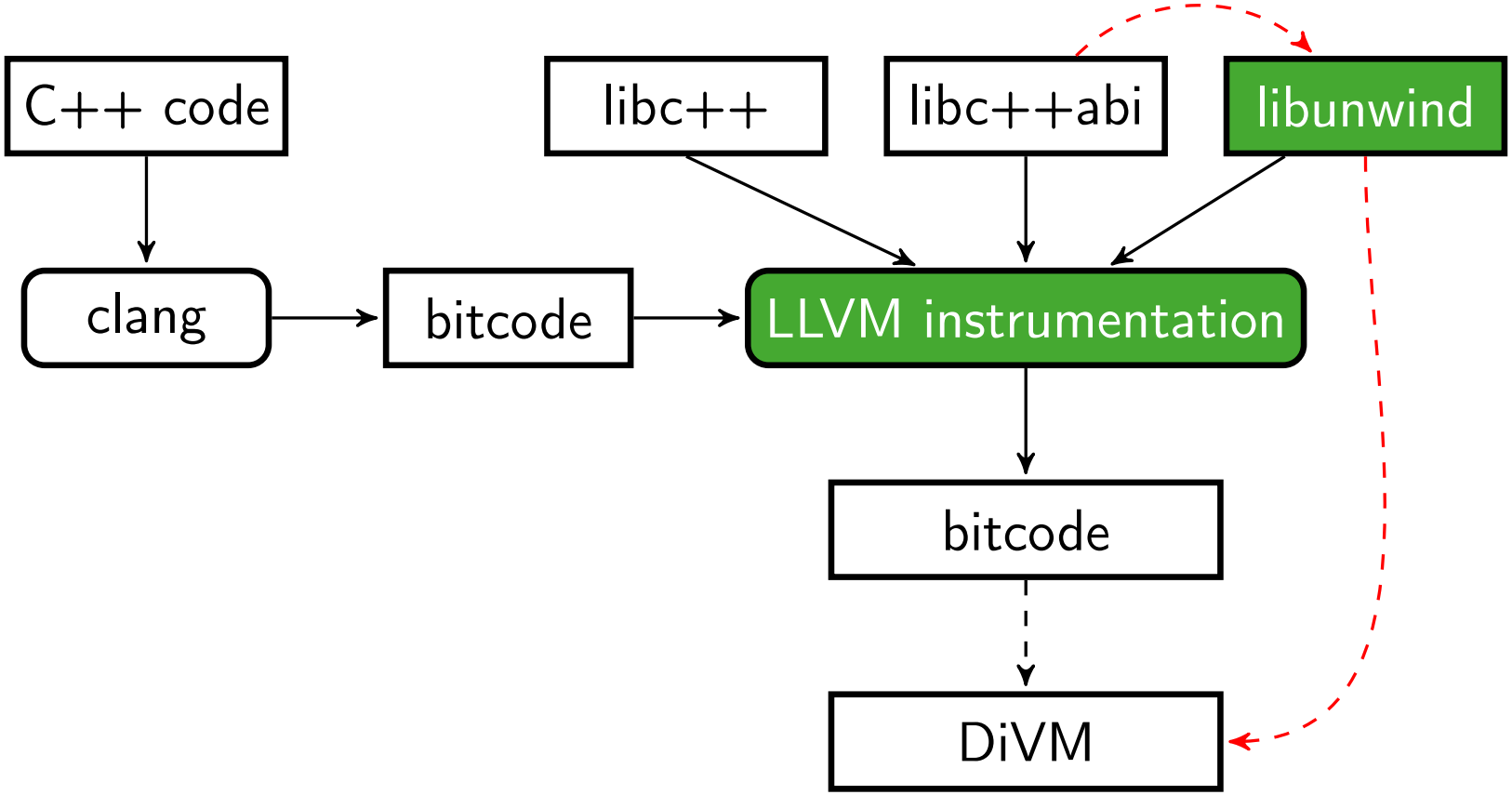

DIVINE/DiVM-specific components

- LLVM-based preprocessing
- DiVM-based implementation of `libunwind`
- approximately 700 lines of new modular C++ code

LLVM Transformation

- exceptions require metadata about stack frames, catch blocks and cleanups for destructors
  - normally describe the machine code
  - DIVINE needs metadata for LLVM bitcode

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  - normally describe the machine code
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- metadata format depends on the implementation of the C++ runtime library
- output of the transformation is LLVM bitcode with additional metadata stored in global constants
- C++ specific encoding of catch and cleanup locations

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- new unwinder for DiVM
- uses metadata from the transformation
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- would also work with other languages

Evaluation & Conclusion

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- reusable and modular implementation of C++ exceptions
- substantial improvement in verification fidelity
- minimal investment: $\sim$ 700 lines of code
- minimal overhead: 2.6 % time overhead compared to an older style of implementation which required changes to the verification core

`divine.fi.muni.cz`
`paradise-fi/divine` on GitHub

more data & code:
`divine.fi.muni.cz/2017/exceptions`