CERIAS

The Center for Education and Research in Information Assurance and Security

HexType: fast type safety for C++ programs

Yuseok Jeon, Hui Peng, Mathias Payer

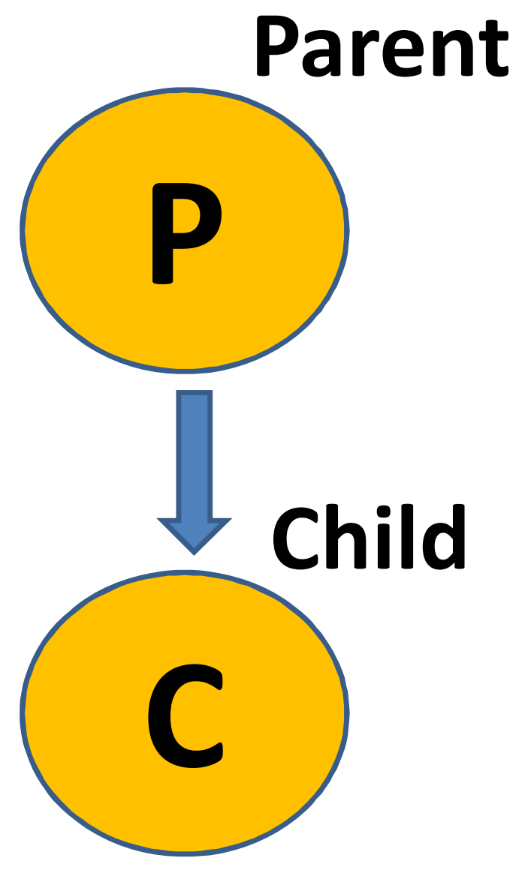
Motivation

- C++ is used in many areas because of its modularity and performance.
- Type-casting converts a pointer from one object type into another.
- Down-casting (converting a base class pointer to a derived class pointer) has critical security implications.
- This vulnerability class has recently received increasing attention and is known as type confusion (unsafe down-casting).
- Several existing solutions are severely limited by both high runtime performance and low coverage (e.g., UBSAN only handles type-casting between polymorphic classes, a small subset of all casts).

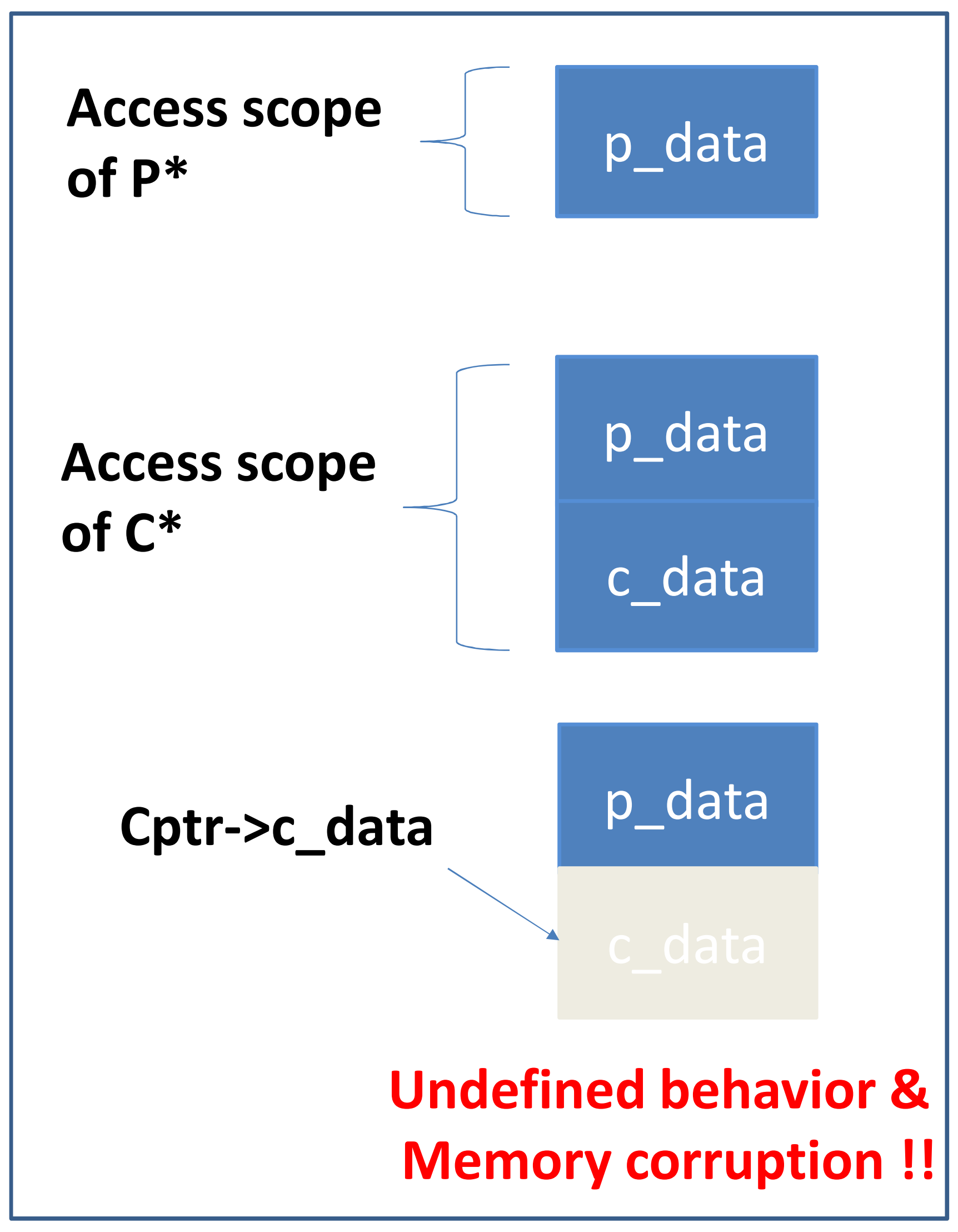
Type Confusion Attack

```
class P {
  int p_data;
};
```

```
class C: public P {
  int c_data;
};
```

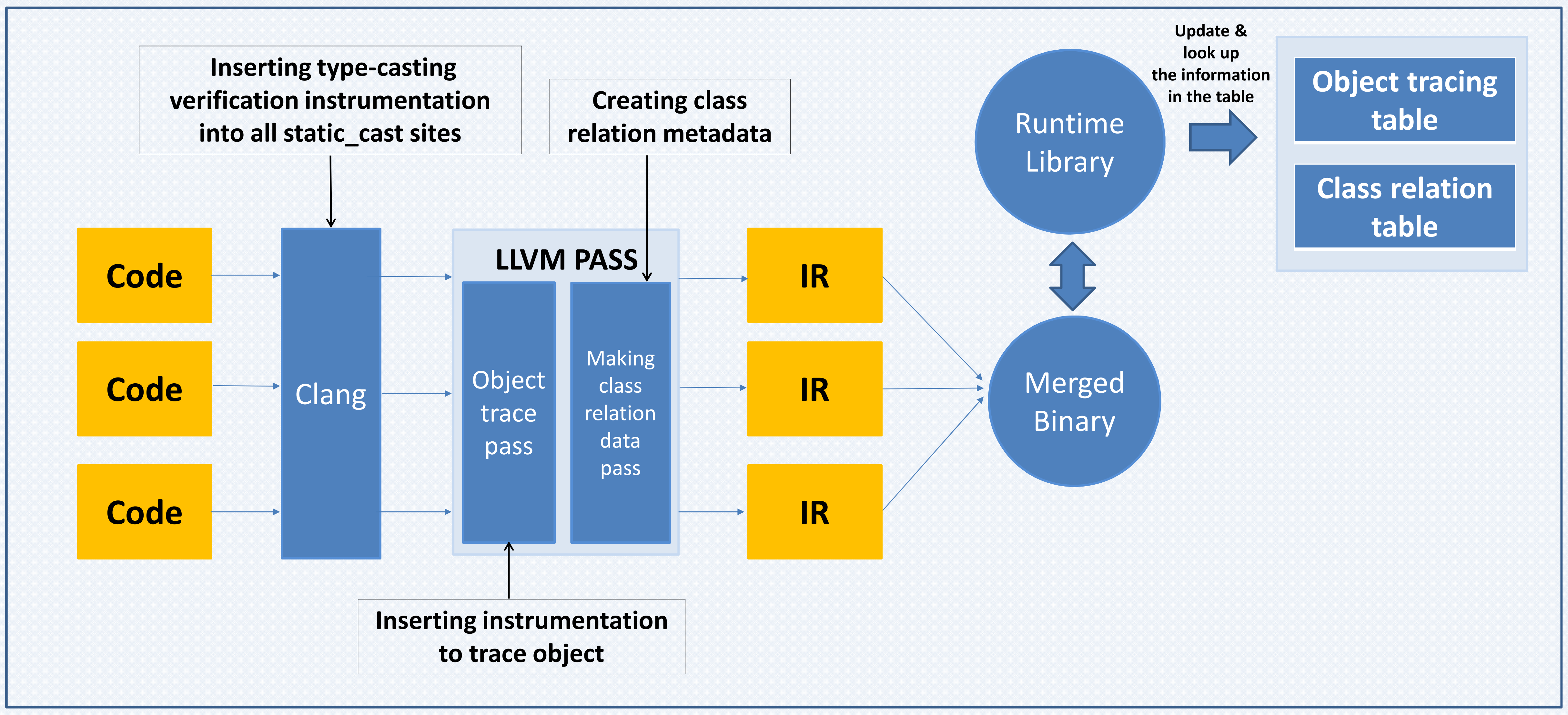


```
P *Pptr = new P;
C *Cptr = static_cast<C*>(Pptr);
Cptr->c_data; (Type confusion!!)
```



Undefined behavior & Memory corruption !!

HexType Architecture


Inserting type-casting verification instrumentation into all static_cast sites
Creating class relation metadata
Code
Code
Code
Clang
LLVM PASS
Object trace pass
Making class relation data pass
IR
IR
IR
Inserting instrumentation to trace object
Runtime Library
Merged Binary
Update & look up the information in the table
Object tracing table
Class relation table

- We introduce a practical technique that has low runtime performance overhead and broad coverage, covering all type casts in an application.
- The source for high runtime overhead of existing approaches is the combination of expensive class relation checks and tracking type information for different memory areas.
- We devise and apply various optimization methods to reduce overhead for class relation checking and tracking type information.

Type Confusion Detection

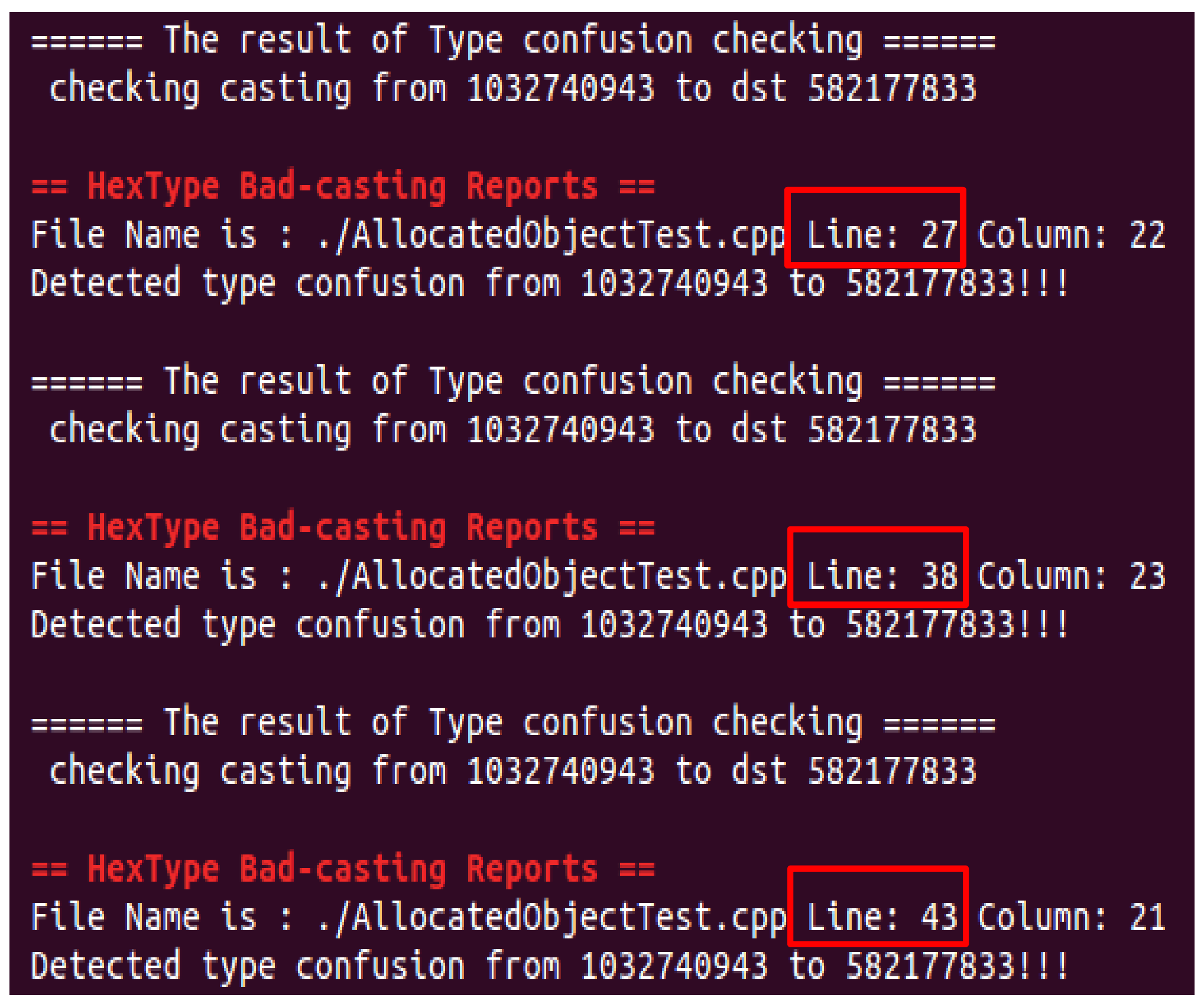
```
P gObj; // declare global variable

int main() {

   // stack object testing
   P sObj;
   P* stackObj = &sObj;
   C* stackTest = static_cast<C*>(stackObj);  //Type Confusion!! (line 27)

   // global object testing
   P* gloObj = &gObj;
   C* globalTest = static_cast<C*>(gloObj);  //Type Confusion!! (line 38)

    // heap object testing
    P* heapObj = new P;
    C* heapTest = static_cast<C*>(heapObj); //Type Confusion!! (line 43)
     .....
}
```



```
====== The result of Type confusion checking ======
 checking casting from 1032740943 to dst 582177833

== HexType Bad-casting Reports ==
File Name is : ./AllocatedObjectTest.cpp Line: 27 Column: 22
Detected type confusion from 1032740943 to 582177833!!!

====== The result of Type confusion checking ======
 checking casting from 1032740943 to dst 582177833

== HexType Bad-casting Reports ==
File Name is : ./AllocatedObjectTest.cpp Line: 38 Column: 23
Detected type confusion from 1032740943 to 582177833!!!

====== The result of Type confusion checking ======
 checking casting from 1032740943 to dst 582177833

== HexType Bad-casting Reports ==
File Name is : ./AllocatedObjectTest.cpp Line: 43 Column: 21
Detected type confusion from 1032740943 to 582177833!!!
```

Conclusion and Future Work

- Previous approaches have limitations to find type confusion vulnerability successfully regarding overhead and coverage.
- Thus, we propose a novel approach with three advantages: (i) full coverage, checking the type information of all casts, (ii) a fast general type check that leverages an indexed per-object metadata table and local information at the current program location, and (iii) low tracking overhead by leveraging architectural features.
- We Plan to:
  - Apply various optimization methods
  - Handle reinterpret and dynamic cast