Debugging Regressions: Interactive Differential Debugging

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Problem

- Modern software systems are complex, with millions of lines of code, making debugging difficult.
- Differential debugging simplifies the process by comparing the current system to a previous version as a baseline.
- Current debugging practice involves running two separate debugger instances without communication about their execution states.

Solution: Interactive Differential Debugging (idd)

IDD automates the process of filtering out irrelevant execution paths between a reference and the regressed software system.

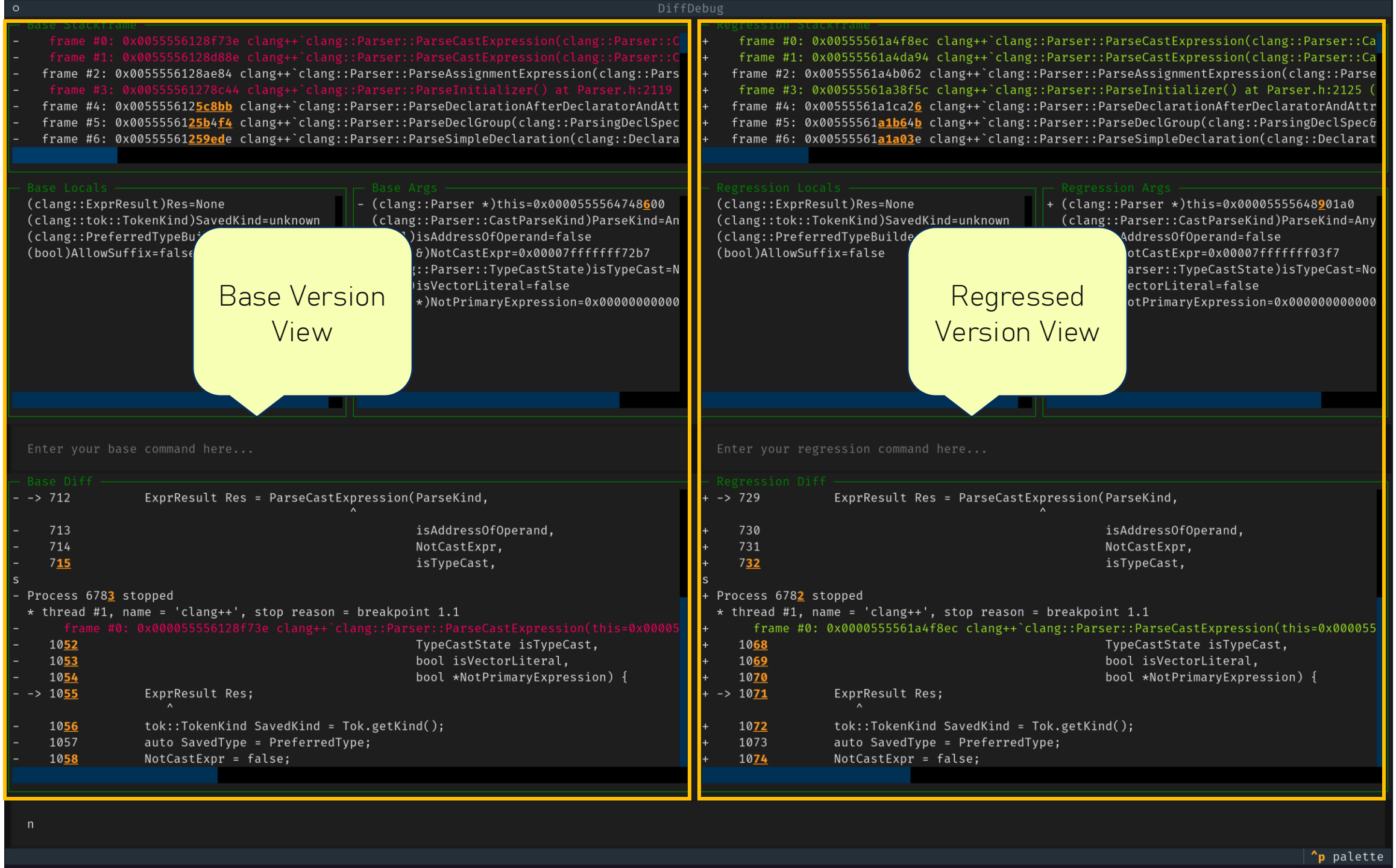
How does it work?

- Load two versions of the system
  - Base: The version of the system we expect to be fine.
  - Regressed: The version that has a regression introduced in it.
- Use LLDB/GDB to inspect both versions of the system simultaneously.
- Leverage diff-view to look at the differences between the states of both systems.
- Deduce the cause of the regression faster by ignoring common/irrelevant execution paths.

The result is a focused display of debugger states that differ between the two versions.

Architecture

- Common place for data exchange between two debuggers. Works with either lldb or gdb.
  - Using lldb python API to steer the lldb debugger.
  - Similar but less powerful approach with gdb due to the limited API supporting tools.
- Git style difference viewer to easily recognize differences between two versions.
- Organizable UI with CSS to concentrate on what matter to you.


DiffDebug
Base StackFrame
- frame #0: 0x0055556128f73e clang++`clang::Parser::ParseCastExpression(clang::Parser::C
- frame #1: 0x0055556128d88e clang++`clang::Parser::ParseCastExpression(clang::Parser::C
- frame #2: 0x0055556128ae84 clang++`clang::Parser::ParseAssignmentExpression(clang::Pars
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Regression StackFrame
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Base Locals
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(clang::tok::TokenKind)SavedKind=unknown
(clang::PreferredTypeBu
(bool)AllowSuffix=false
Base Args
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(clang::Parser::CastParseKind)ParseKind=An
)isAddressOfOperand=false
&)NotCastExpr=0x00007fffffff72b7
::Parser::TypeCastState)isTypeCast=N
)isVectorLiteral=false
*)NotPrimaryExpression=0x000000000000
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Base Version View
Regressed Version View
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Enter your regression command here...
Base Diff
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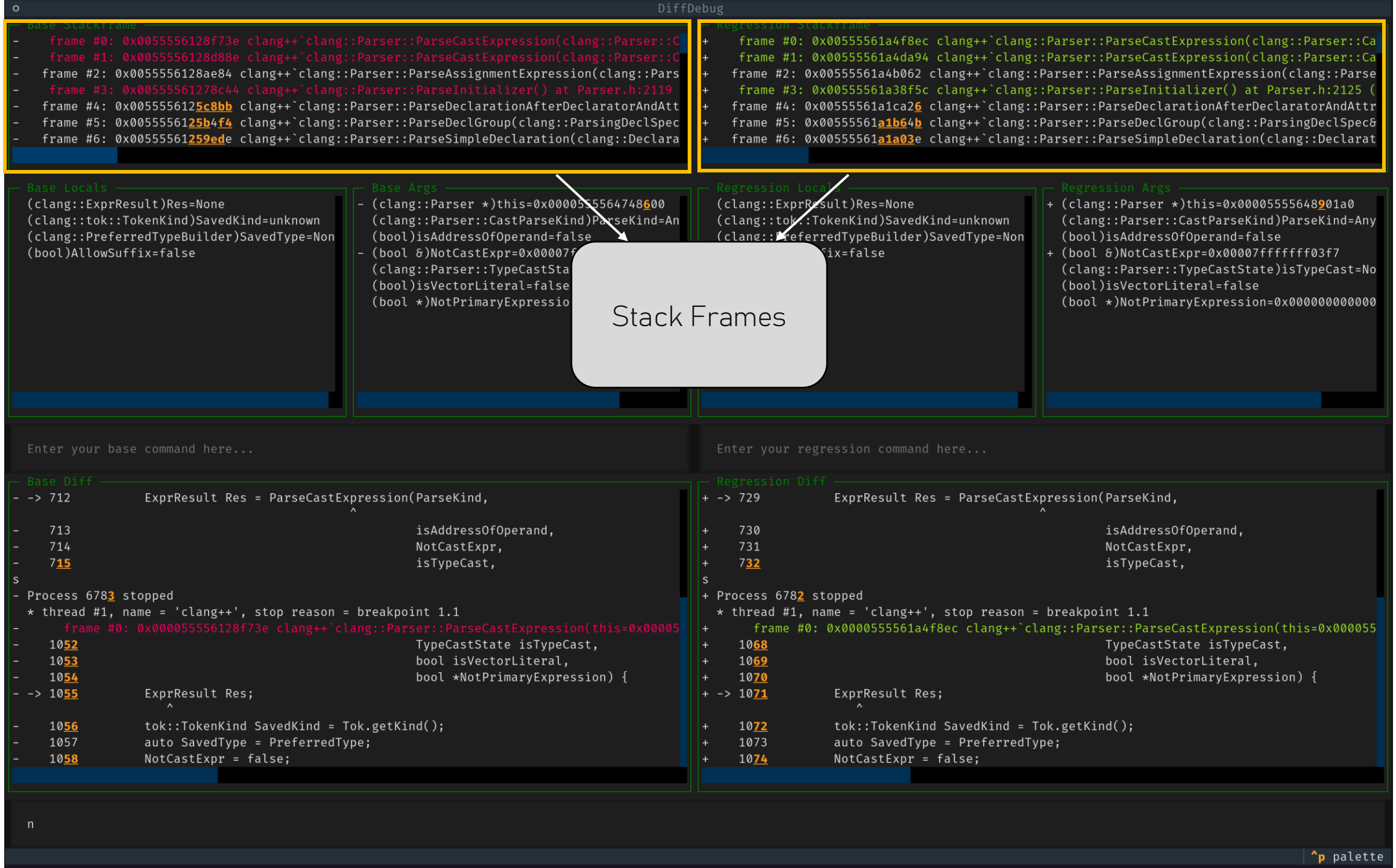
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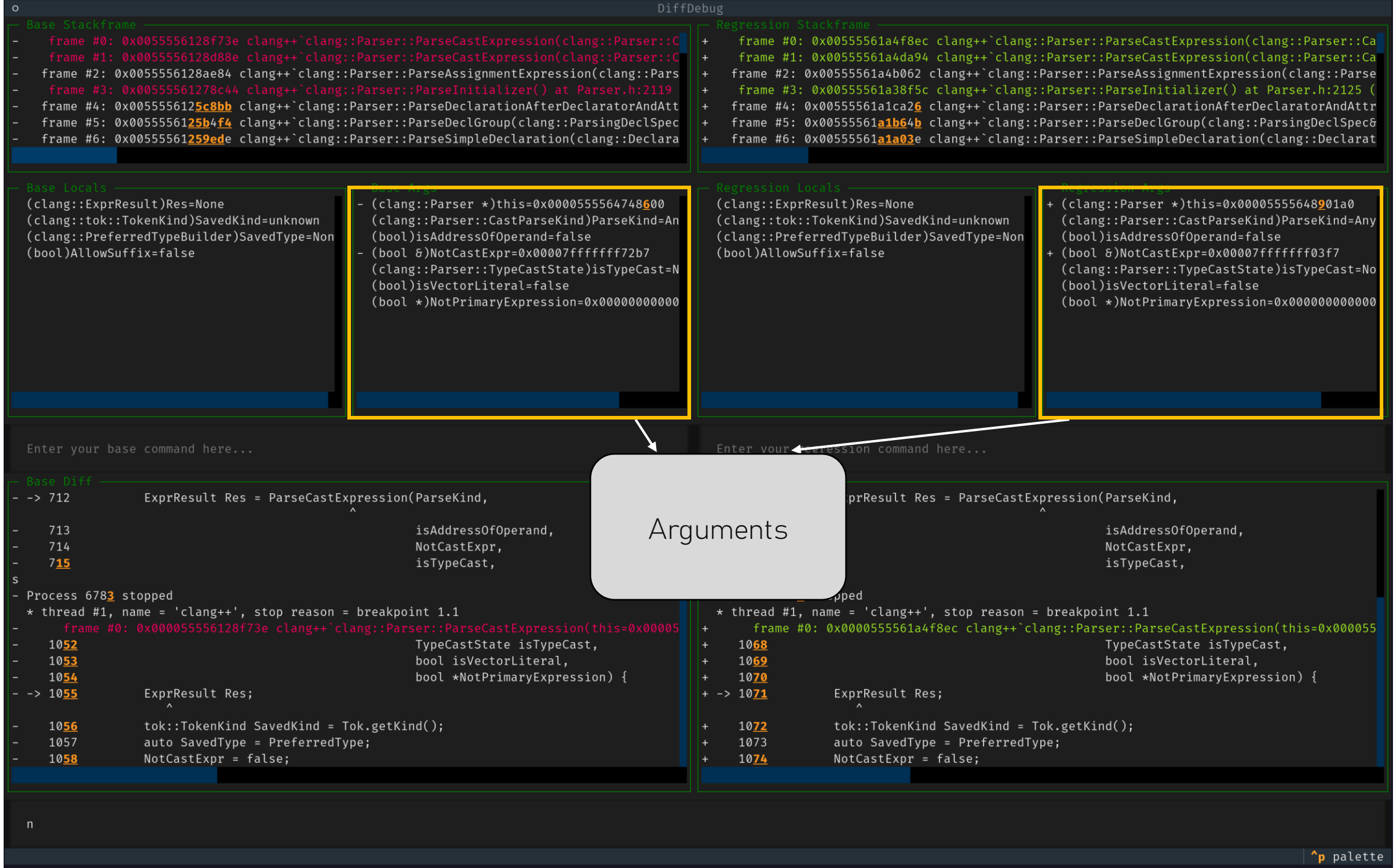
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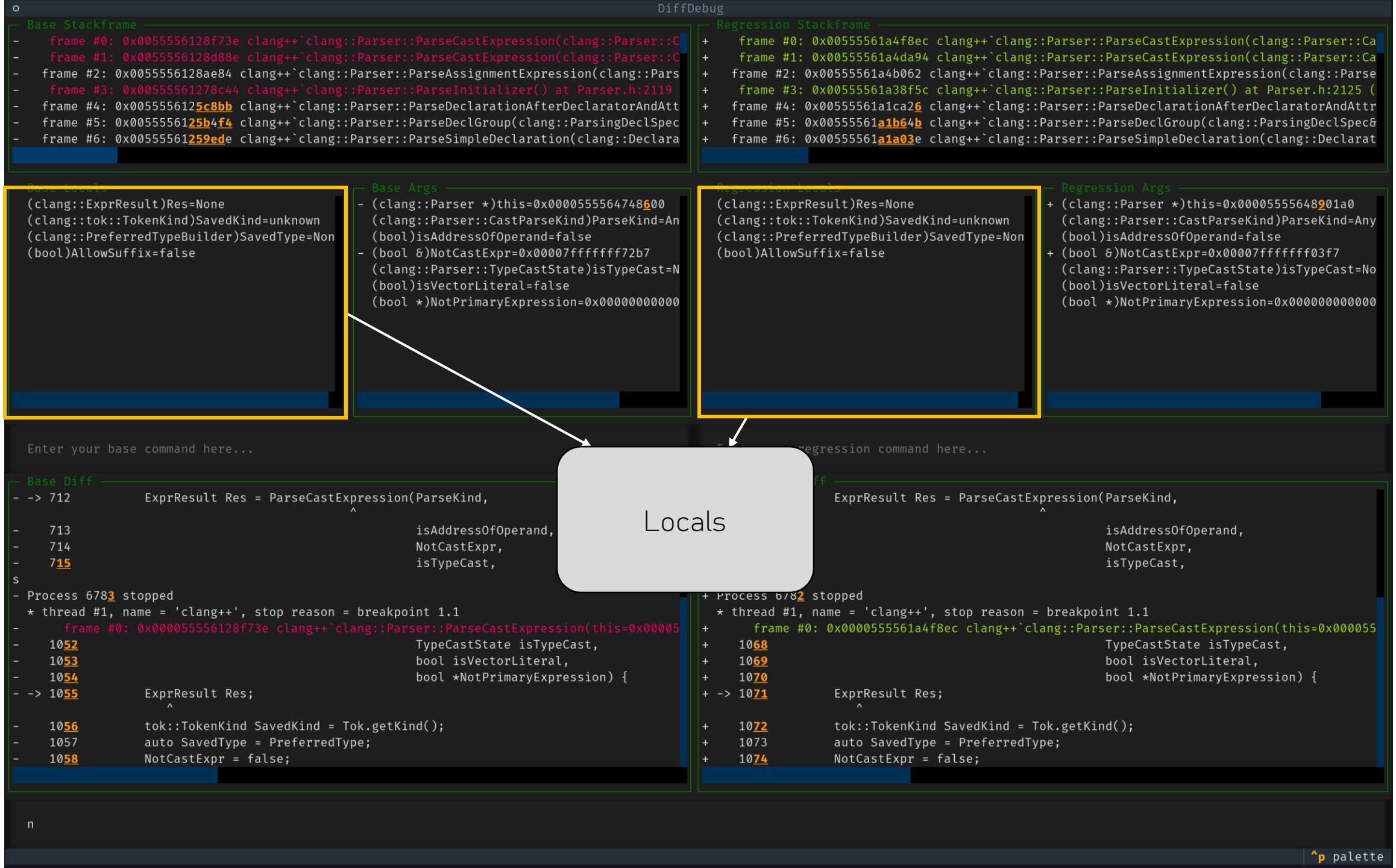
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Enter your base command here...
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Locals
Base Diff
- -> 712 ExprResult Res = ParseCastExpression(ParseKind,
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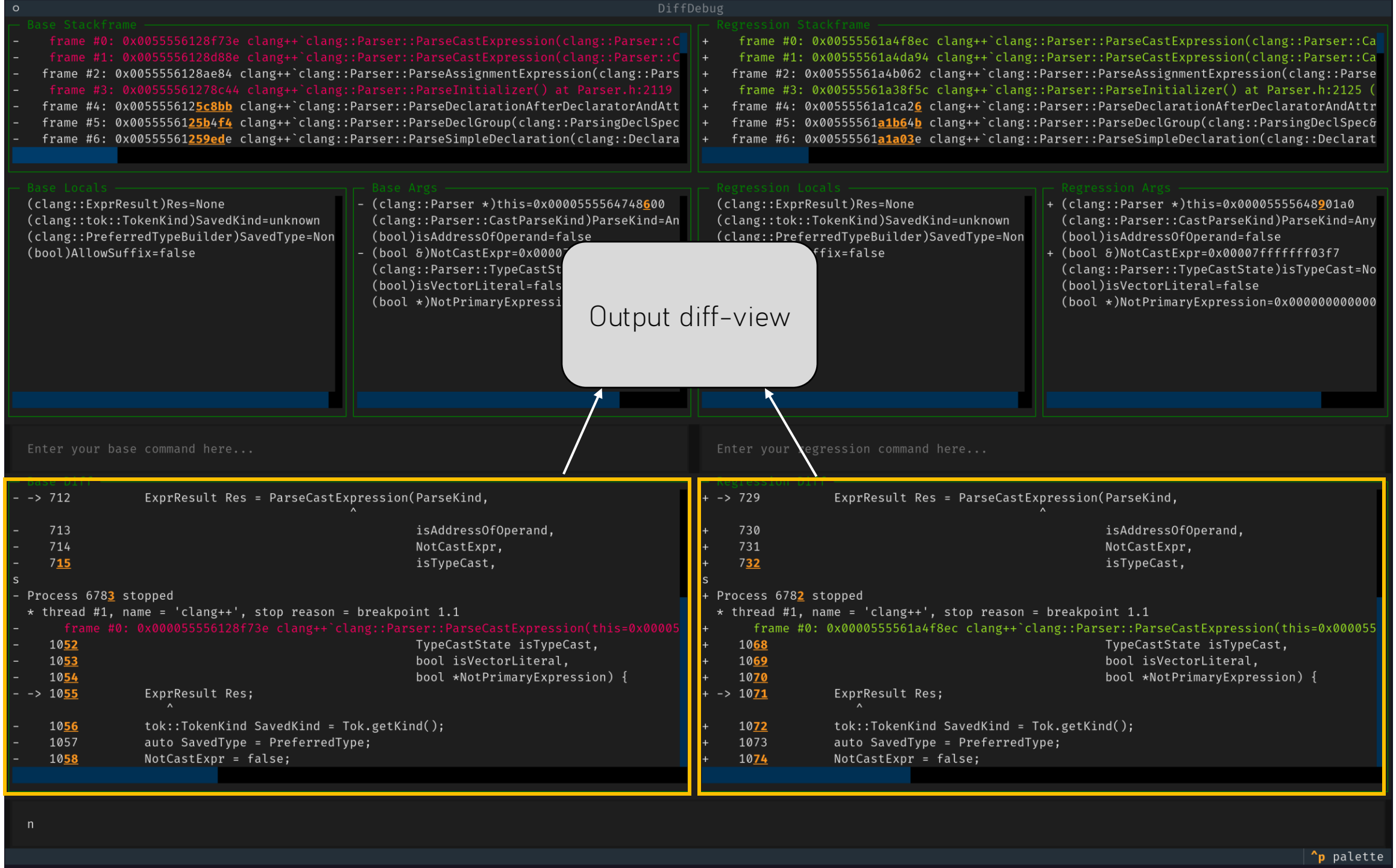
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Output diff-view
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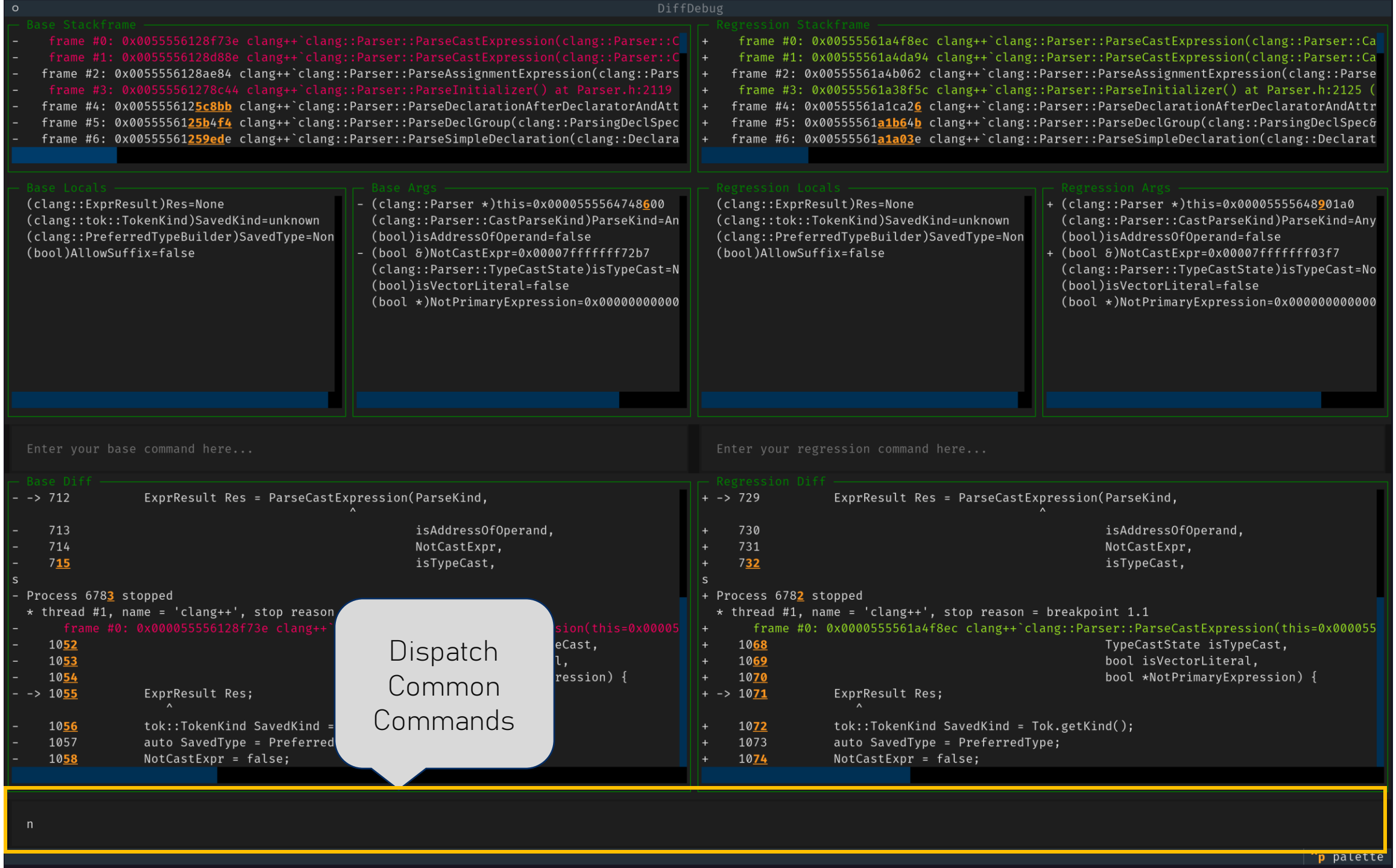
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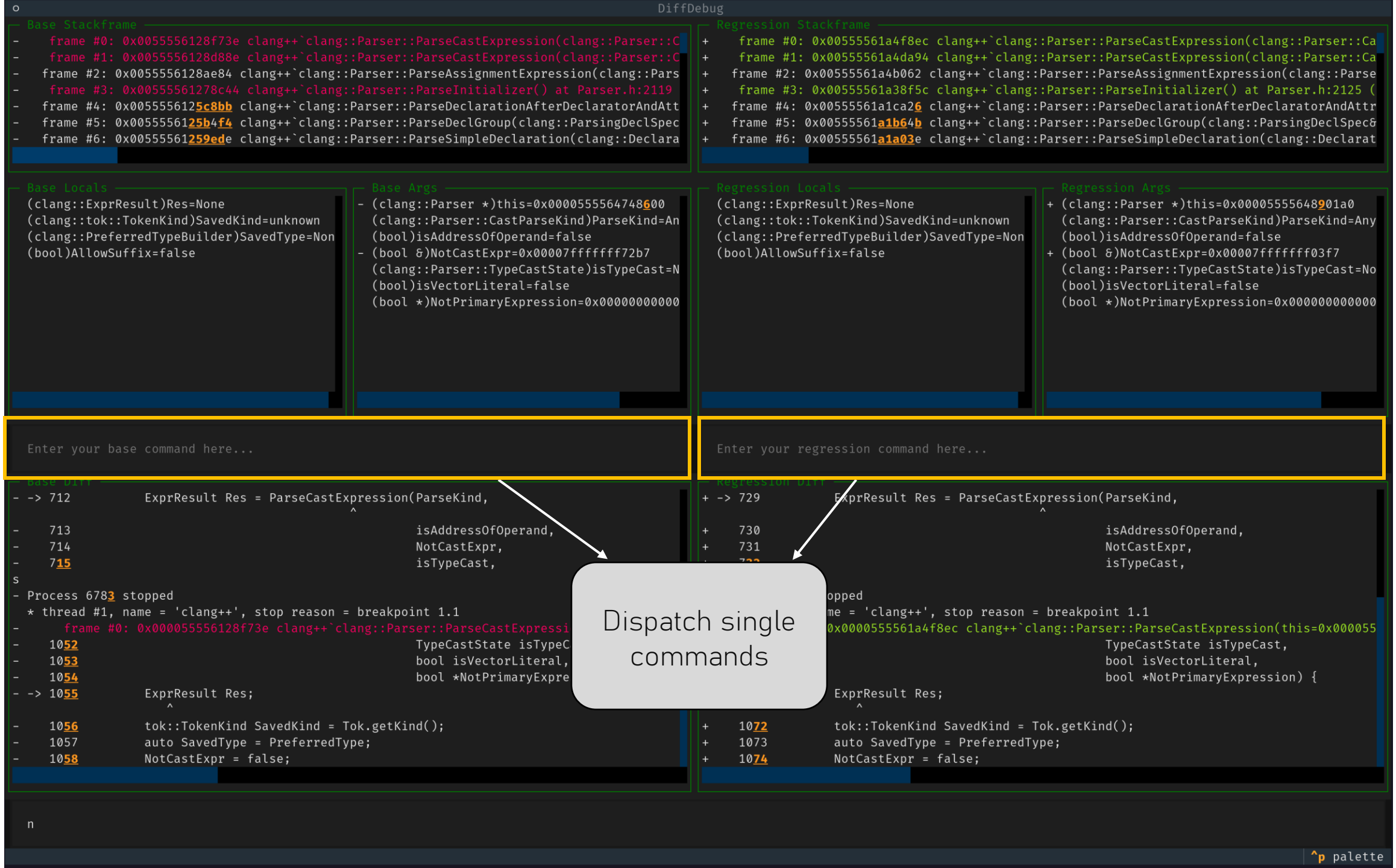
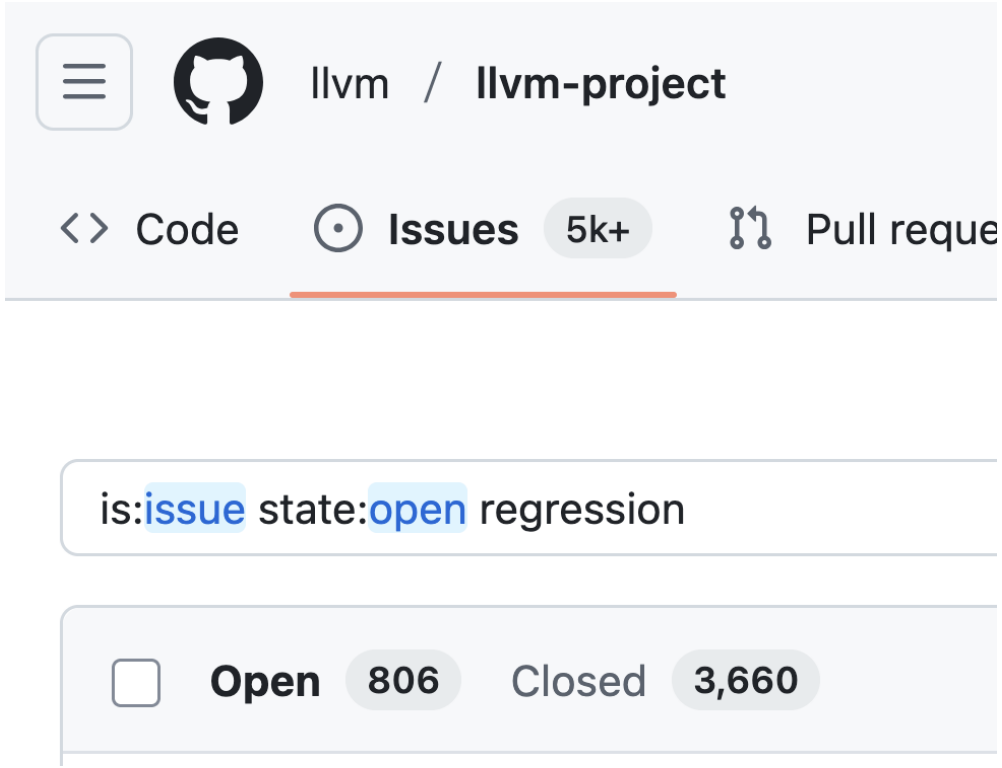
(bool)isAddressOfOperand=false
- (bool &)NotCastExpr=0x00007fffffff72b7
(clang::Parser::TypeCastState)isTypeCast=N
(bool)isVectorLiteral=false
(bool *)NotPrimaryExpression=0x00000000000
Regression Locals
(clang::ExprResult)Res=None
(clang::tok::TokenKind)SavedKind=unknown
(clang::PreferredTypeBuilder)SavedType=Non
(bool)AllowSuffix=false
Regression Args
+ (clang::Parser *)this=0x0000555564801a0
(clang::Parser::CastParseKind)ParseKind=Any
(bool)isAddressOfOperand=false
+ (bool &)NotCastExpr=0x00007fffffff03f7
(clang::Parser::TypeCastState)isTypeCast=No
(bool)isVectorLiteral=false
(bool *)NotPrimaryExpression=0x00000000000
Enter your base command here...
Enter your regression command here...
Base Diff
- -> 712 ExprResult Res = ParseCastExpression(ParseKind,
^
- 713 isAddressOfOperand,
- 714 NotCastExpr,
- 715 isTypeCast,
s
- Process 6783 stopped
* thread #1, name = 'clang++', stop reason
- frame #0: 0x00005556128f73e clang++`
sion(this=0x00005
- 1052 eCast,
- 1053 l,
- 1054 ression) {
- -> 1055 ExprResult Res;
^
- 1056 tok::TokenKind SavedKind =
- 1057 auto SavedType = Preferred
- 1058 NotCastExpr = false;
Regression Diff
+ -> 729 ExprResult Res = ParseCastExpression(ParseKind,
^
+ 730 isAddressOfOperand,
+ 731 NotCastExpr,
+ 732 isTypeCast,
s
+ Process 6782 stopped
* thread #1, name = 'clang++', stop reason = breakpoint 1.1
+ frame #0: 0x0000555561a4f8ec clang++`clang::Parser::ParseCastExpression(this=0x000055
+ 1068 TypeCastState isTypeCast,
+ 1069 bool isVectorLiteral,
+ 1070 bool *NotPrimaryExpression) {
+ -> 1071 ExprResult Res;
^
+ 1072 tok::TokenKind SavedKind = Tok.getKind();
+ 1073 auto SavedType = PreferredType;
+ 1074 NotCastExpr = false;
Dispatch Common Commands
n
^p palette


DiffDebug
Base Stackframe
- frame #0: 0x0055556128f73e clang++`clang::Parser::ParseCastExpression(clang::Parser::C
- frame #1: 0x0055556128d88e clang++`clang::Parser::ParseCastExpression(clang::Parser::C
- frame #2: 0x0055556128ae84 clang++`clang::Parser::ParseAssignmentExpression(clang::Pars
- frame #3: 0x00555561278c44 clang++`clang::Parser::ParseInitializer() at Parser.h:2119
- frame #4: 0x0055556125c8bb clang++`clang::Parser::ParseDeclarationAfterDeclaratorAndAtt
- frame #5: 0x0055556125b4f4 clang++`clang::Parser::ParseDeclGroup(clang::ParsingDeclSpec
- frame #6: 0x0055556125 9ede clang++`clang::Parser::ParseSimpleDeclaration(clang::Declara
Regression Stackframe
+ frame #0: 0x00555561a4f8ec clang++`clang::Parser::ParseCastExpression(clang::Parser::Ca
+ frame #1: 0x00555561a4da94 clang++`clang::Parser::ParseCastExpression(clang::Parser::Ca
+ frame #2: 0x00555561a4b062 clang++`clang::Parser::ParseAssignmentExpression(clang::Parse
+ frame #3: 0x00555561a38f5c clang++`clang::Parser::ParseInitializer() at Parser.h:2125 (
+ frame #4: 0x00555561a1ca26 clang++`clang::Parser::ParseDeclarationAfterDeclaratorAndAttr
+ frame #5: 0x00555561a1b64b clang++`clang::Parser::ParseDeclGroup(clang::ParsingDeclSpec&
+ frame #6: 0x00555561a1a03e clang++`clang::Parser::ParseSimpleDeclaration(clang::Declarat
Base Locals
(clang::ExprResult)Res=None
(clang::tok::TokenKind)SavedKind=unknown
(clang::PreferredTypeBuilder)SavedType=Non
(bool)AllowSuffix=false
Base Args
- (clang::Parser *)this=0x0000555564748600
(clang::Parser::CastParseKind)ParseKind=An
(bool)isAddressOfOperand=false
- (bool &)NotCastExpr=0x00007fffffff72b7
(clang::Parser::TypeCastState)isTypeCast=N
(bool)isVectorLiteral=false
(bool *)NotPrimaryExpression=0x00000000000
Regression Locals
(clang::ExprResult)Res=None
(clang::tok::TokenKind)SavedKind=unknown
(clang::PreferredTypeBuilder)SavedType=Non
(bool)AllowSuffix=false
Regression Args
+ (clang::Parser *)this=0x0000555564 901a0
(clang::Parser::CastParseKind)ParseKind=Any
(bool)isAddressOfOperand=false
+ (bool &)NotCastExpr=0x00007fffffff03f7
(clang::Parser::TypeCastState)isTypeCast=No
(bool)isVectorLiteral=false
(bool *)NotPrimaryExpression=0x000000000000
Enter your base command here...
Enter your regression command here...
Base Diff
- -> 712 ExprResult Res = ParseCastExpression(ParseKind,
^
- 713 isAddressOfOperand,
- 714 NotCastExpr,
- 715 isTypeCast,
s
- Process 67883 stopped
* thread #1, name = 'clang++', stop reason = breakpoint 1.1
- frame #0: 0x00005556128f73e clang++`clang::Parser::ParseCastExpressi
- 1052 TypeCastState isTypeC
- 1053 bool isVectorLiteral,
- 1054 bool *NotPrimaryExpre
- -> 1055 ExprResult Res;
^
- 1056 tok::TokenKind SavedKind = Tok.getKind();
- 1057 auto SavedType = PreferredType;
- 1058 NotCastExpr = false;
Regression Diff
+ -> 729 ExprResult Res = ParseCastExpression(ParseKind,
^
+ 730 isAddressOfOperand,
+ 731 NotCastExpr,
isTypeCast,
opped
me = 'clang++', stop reason = breakpoint 1.1
0x0000555561a4f8ec clang++`clang::Parser::ParseCastExpression(this=0x000055
TypeCastState isTypeCast,
bool isVectorLiteral,
bool *NotPrimaryExpression) {
ExprResult Res;
^
+ 1072 tok::TokenKind SavedKind = Tok.getKind();
+ 1073 auto SavedType = PreferredType;
+ 1074 NotCastExpr = false;
Dispatch single commands
n
^p palette

Advantages

Differential Debugging is not restricted to finding regressions in the codebase.

- Bug Localization in Regression Analysis
- Migration and Third-Party Library Updates
- Debugging Across Compiler Optimizations



Time for Demonstration

Future Work

- Improved semantic diff. E.g. Address Space Randomization (ALSR)
- Automatically halt execution at diverging stack frames
- Watchpoints for diverging variables of interest

These enhancements would reduce manual effort, accelerate bug localization, and improve the overall user experience of IDD.

Thank You

Any Questions?

🔗 GitHub: github.com/compiler-research/idd

📦 PyPI: pypi.org/project/idd

📌 Install via: **pip install idd**