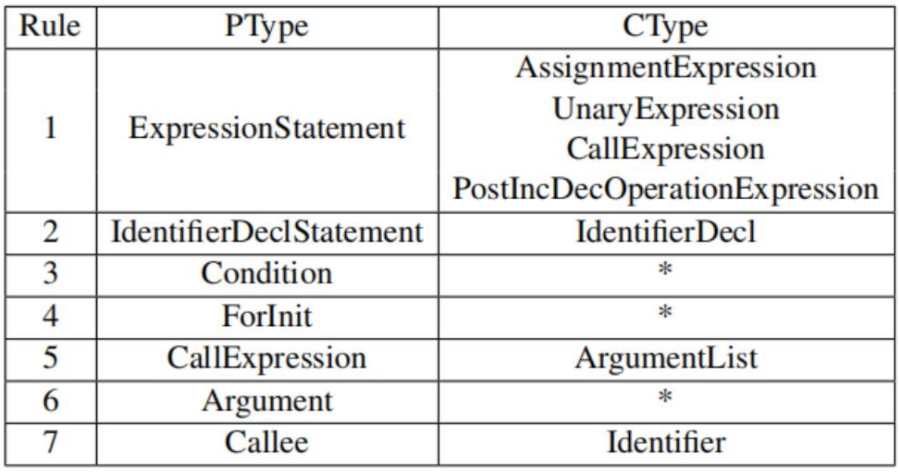
As shown in the table below, we identified seven merging rules for type-based graph simplification:

TABLE I: Merging rules in type-based graph simplification. “PType” and “CType” indicate the types of the parent and child nodes of a directed edge, respectively. The * represents any node type, and the PType “Augment” in Rule 6 represents the parameters of function call statements.



Rule	PType	CType
1	ExpressionStatement	AssignmentExpression UnaryExpression CallExpression PostIncDecOperationExpression
2	IdentifierDeclStatement	IdentifierDecl
3	Condition	*
4	ForInit	*
5	CallExpression	ArgumentList
6	Argument	*
7	Callee	Identifier

For each rule in the table (except rule 2, which has an example in our paper), we give a detailed example and explain the reason for the merge operation. In the following graphs, each node has two attributes: the first line of text in the node means the value and the second line of text in the node means the type.

Rule 1

(ExpressionStatement, AssignmentExpression)

Figure 1.1 is the AST of statement "commandLength = strlen (cat) + strlen(argv[1]) + 1". According to rule 1, node 2 is merged into node 1. The value of node 2 is repetitive with the value of node 1, and the value information of node 2 is also reflected in its descendant nodes.

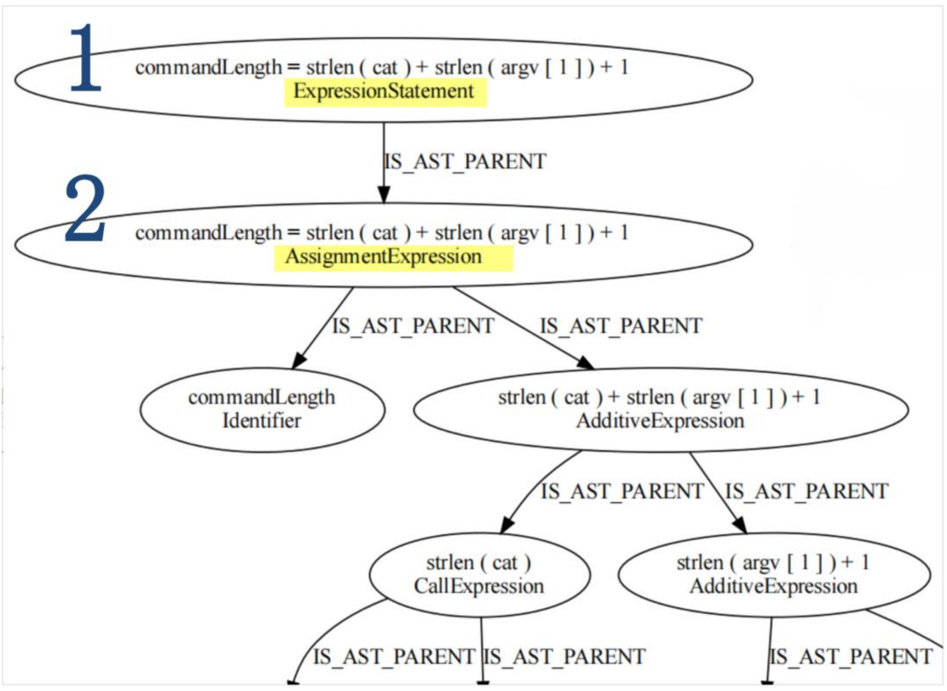


Figure 1.1. Rule 1: (ExpressionStatement, AssignmentExpression)

(ExpressionStatement, UnaryExpression)

Figure 1.2 is the AST of statement “++i;”. Node 2 is merged into node 1. The value of node 2 is repetitive with the value of node 1, and the value information of node 2 is also reflected in its descendant nodes.

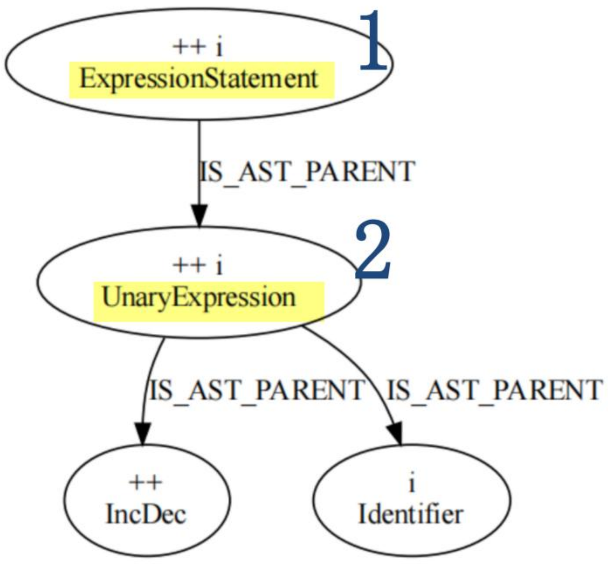


Figure 1.2. Rule 1: (ExpressionStatement, UnaryExpression)

(ExpressionStatement, CallExpression)

Figure 1.3 is the AST of statement “strncpy (command, cat, commandLength) ”. According to rule 1, node 2 is merged into node 1. The value of node 2 is repetitive with the value of node 1, and the value information of node 2 is also reflected in its descendant nodes.

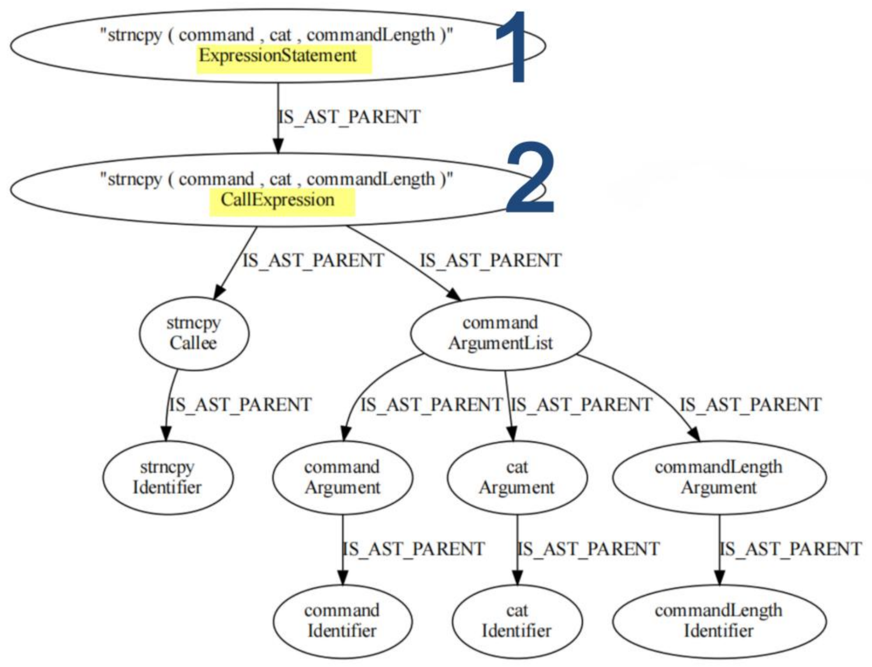


Figure 1.3. Rule 1: (ExpressionStatement, CallExpression)

(ExpressionStatement, PostIncDecOperationExpression)

Figure 1.4 is the AST of statement “i++”. Node 2 is merged into node 1. The value of node 2 is repetitive with the value of node 1, and the value information of node 2 is also reflected in its descendant nodes.

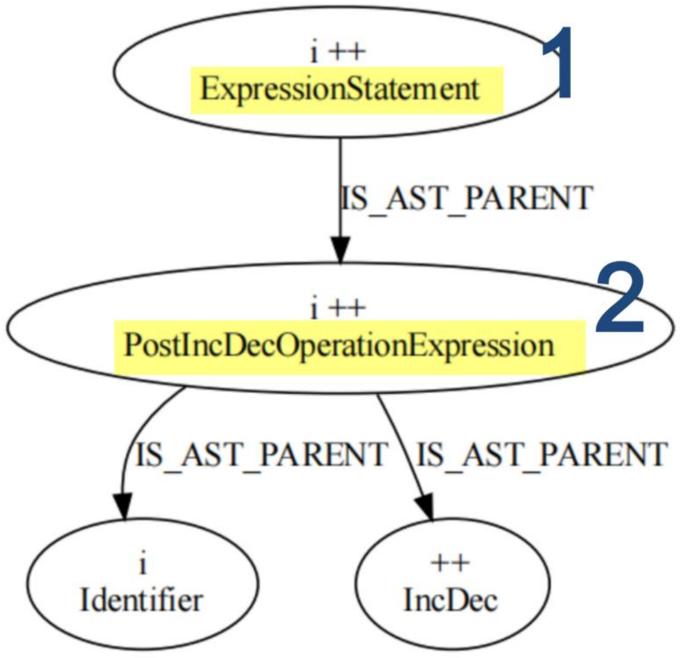


Figure 1.4. Rule 1: (ExpressionStatement, PostIncDecOperationExpression)

Rule 3 (Condition, RelationalExpression)

Figure 3 is the AST of statement “if(MAX_SIZE <= strlen (user_supplied_string)”, and node 2 is merged into node 1. The value of node 2 is repetitive with the value of node 1, and the value information of node 2 is also reflected in its descendant nodes.

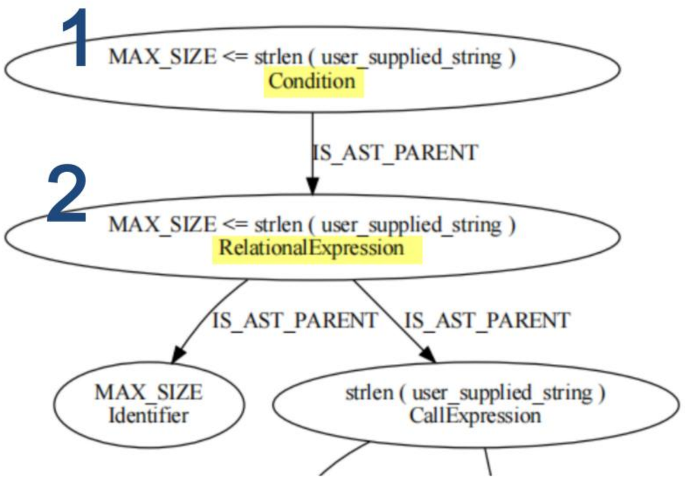

1
MAX_SIZE <= strlen (user_supplied_string)
Condition
IS_AST_PARENT
2
MAX_SIZE <= strlen (user_supplied_string)
RelationalExpression
IS_AST_PARENT
IS_AST_PARENT
MAX_SIZE
Identifier
strlen (user_supplied_string)
CallExpression

Figure 3. Rule 3: (Condition, RelationalExpression)

Rule 4 (ForInit, *)

As shown in Figure 4, the AST is about the statement “i=0” which is contained in the for-loop statement “for (i = 0; i < 10; i++){}” or “for (i = 0; i < 10;){}” or “for (i = 0; ;){}”. Node 2 is merged into node 1. The value of node 2 is repetitive with the value of node 1, and the value information of node 2 is also reflected in its descendant nodes.

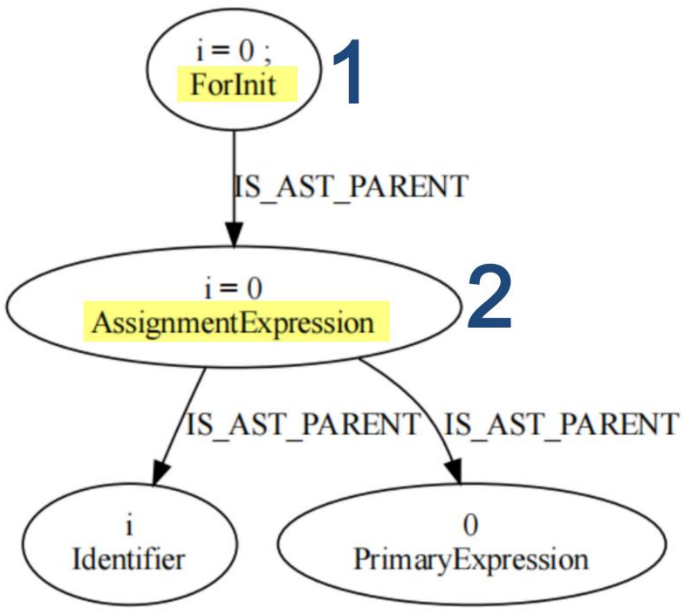


Figure 4. Rule 4: (ForInit, *)

Rule 5 (CallExpression, ArgumentList)

As shown in Figure 5, node 2 is merged into node 1. Although the type of node 2 is “ArgumentList” that means the parameter list, the value of node 2 only contains the first parameter of the function “strncpy”. And the three child nodes of node 2: nodes 3-5 represents the three parameters of the function “strncpy” respectively. So we merge the node 2 into node 1.

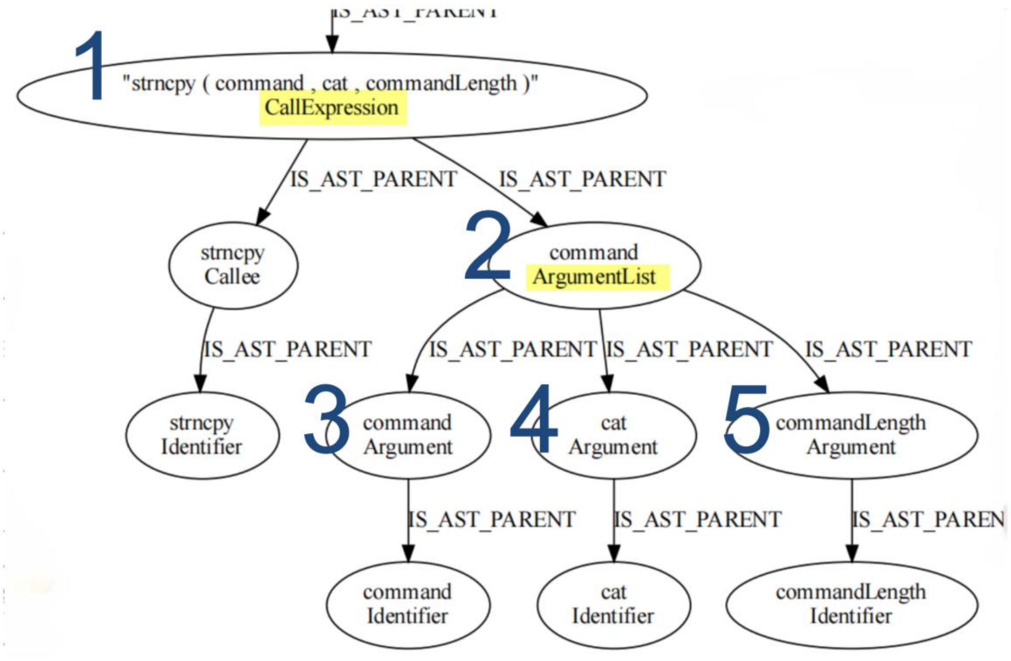


Figure 5. Rule 5: (CallExpression, ArgumentList)

Rule 6 (Argument, *)

As shown in Figure 6, nodes 1,3,5 are merged into nodes 2,4,6 respectively. Nodes 1 and 2 have the same value (Nodes 3,4 and nodes 5,6 also the same respectively). Merging nodes 1 and 2 can reduce the depth of the AST and reduce the size of the code structure graph.

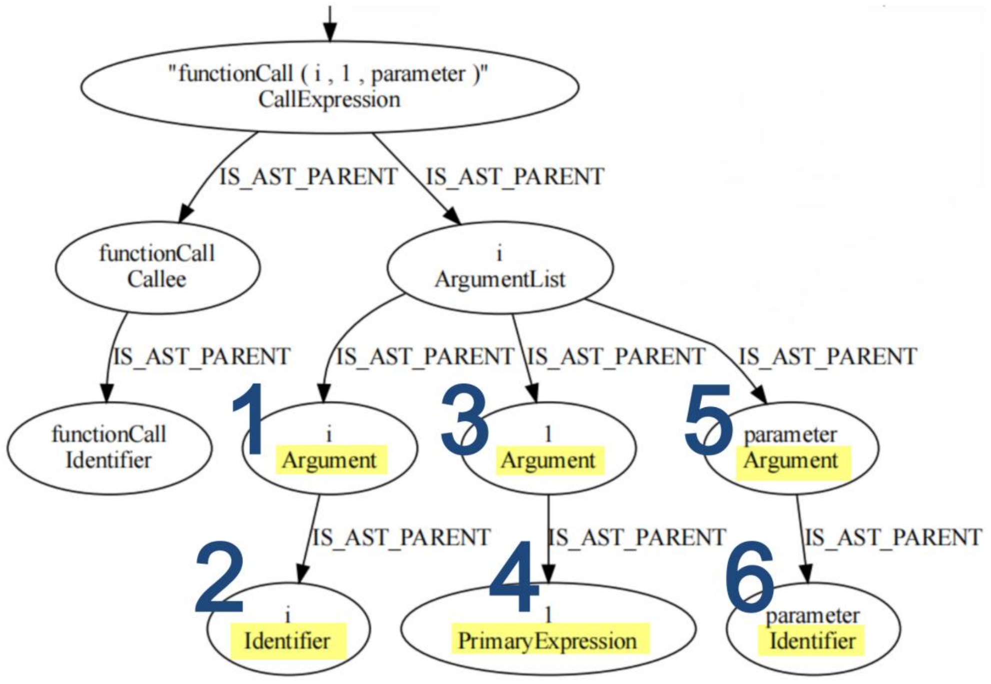


Figure 6. Rule 6: (Argument, *)

Rule 7 (Callee, Identifier)

As shown in Figure 7, node 2 is merged into node 1. Nodes 1, 2 have the same value. The “Identifier” type of node 2 is a refinement of the “Callee” type of node 1. Merging them can reduce the depth of the AST and shrink the size of the code structure graph.

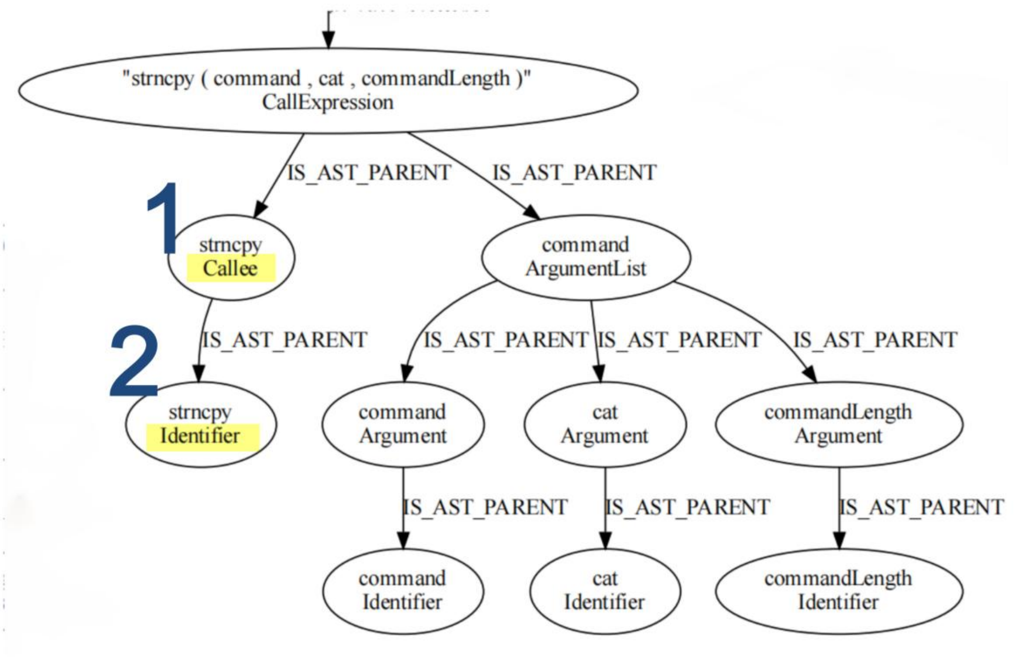


Figure 7. Rule 7: (Callee, Identifier)