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# Grafter: A Clang tool for tree traversals fusion

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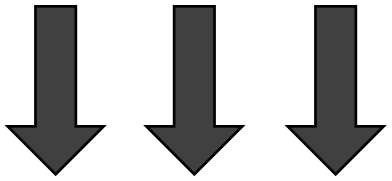
# What is Grafter?

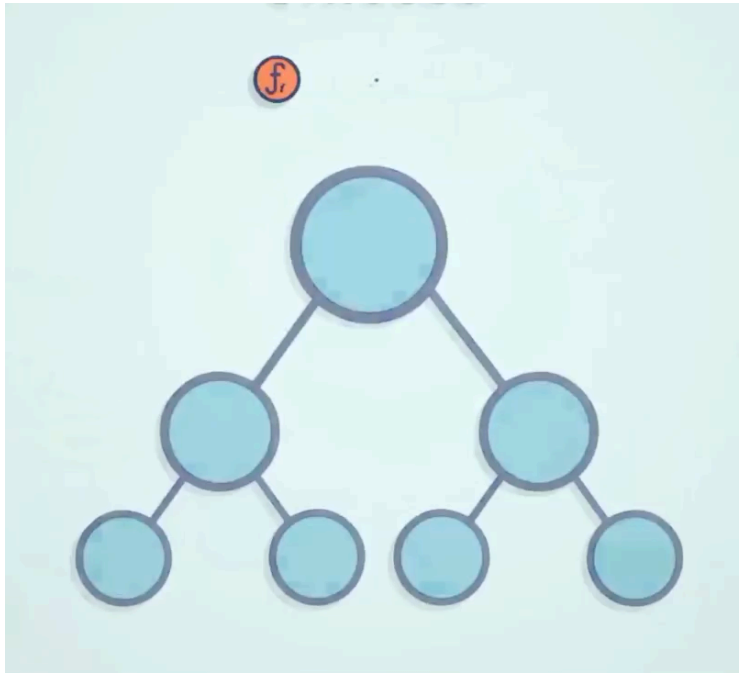
Grafter performs source to source transformations to fuse recursive functions that traverse trees

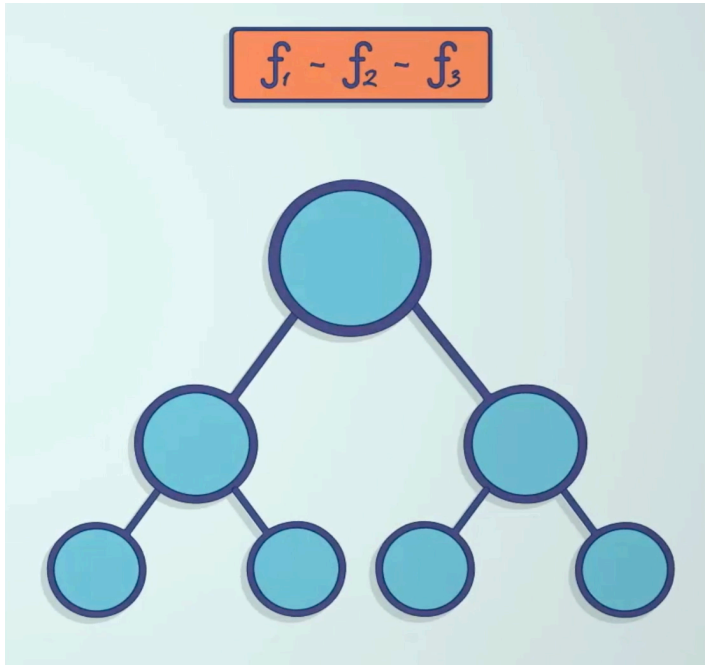
```
computeHight (render_tree);
computeWidth(render_tree);
computePos(render_tree);
```



```
computeHight_ computeWidth_computePos(render_tree);
```

# What is Grafter?




Sound, Fine-Grained Traversal Fusion for Heterogeneous Trees (PLDI 2019)
https://dl.acm.org/citation.cfm?id=3314221.3314626
https://www.youtube.com/watch?v=j2henSFtZds
https://github.com/laithsakka/Grafter

# This talk is not about Grafter!
# Its about utilizing Clang to implement Grafter

1. Embedded DSL in C++

2. Static analysis

3. Code generation

# Why embedded DSL in C++

- Better Productivity.
- Better Performance.
- Ease of Integration.

# Embedded DSL in C++

- Annotate components
- Verify annotated components against a set of rules.

Annotations

```
class __tree_structure__ ValueNode : public Node {
public:
  int Value;
  __tree_child__ Node *Left, *Right;

  __tree_traversal__ void search(int Key, bool ValidCall) override {
    Found = false;
    if (Key == Value) {
      Found = true;
      return;
    }
    Left->search(Key, Key < Value);
    Right->search(Key, Key >= Value);
    Found = Left->Found || Right->Found;
  }
}
```

**No aliasing**

```
this->Left = this->Right;
this->Left = new ValueNode();
```

**No condition calls**

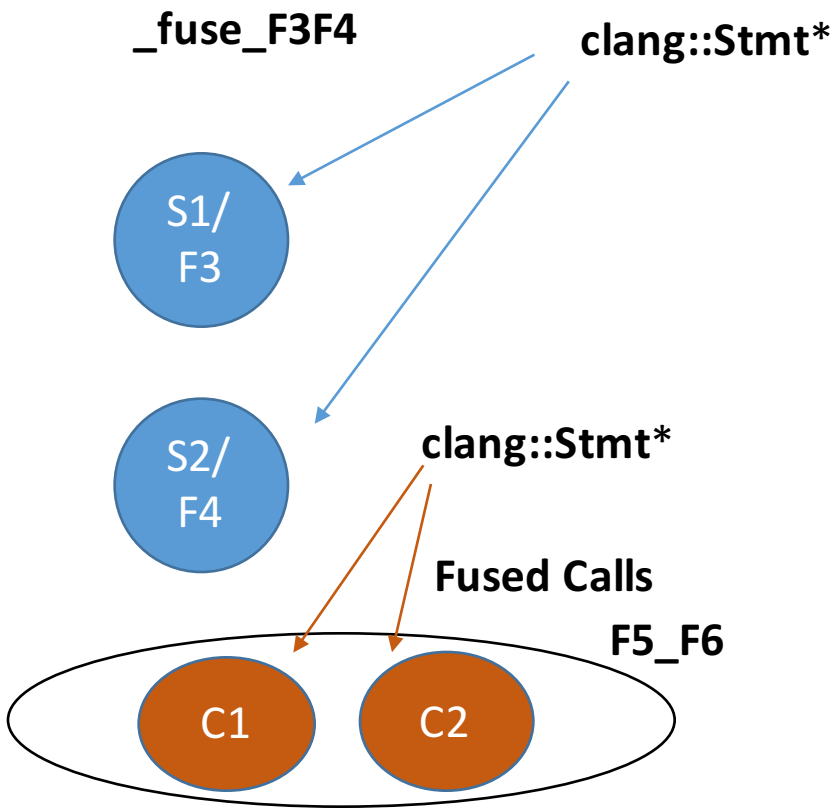
```
if(...)
  Left->insert(...)

Left->insert(...)
```

# Static analysis

1. A function is represented as a sequence of Clang::Stmt* and Clang::CallExpr* nodes.

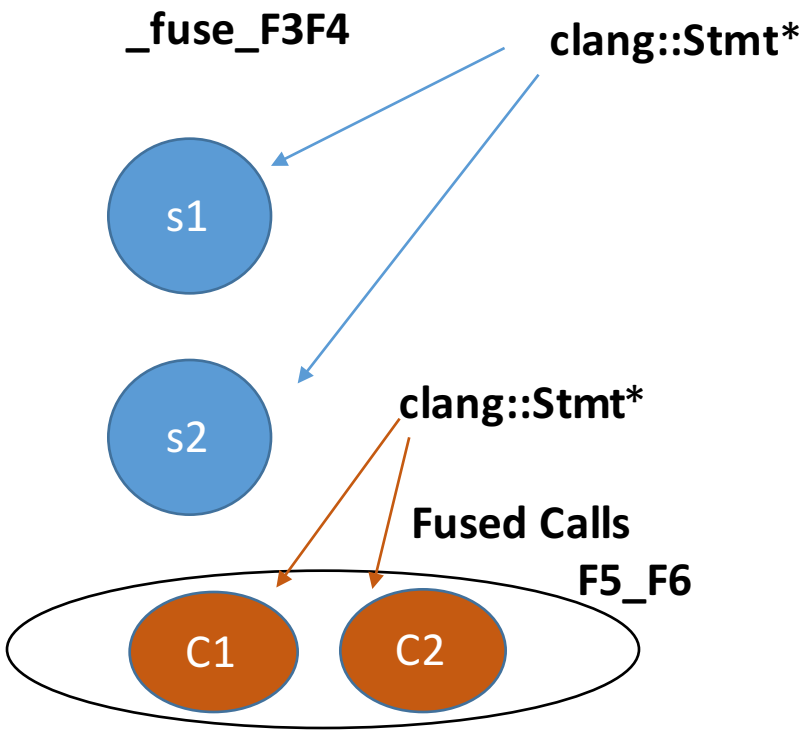
   Different schedules are achieved by reordering statements and collapsing calls.

2. Understand accesses of statements and build call graphs to analyze dependences.



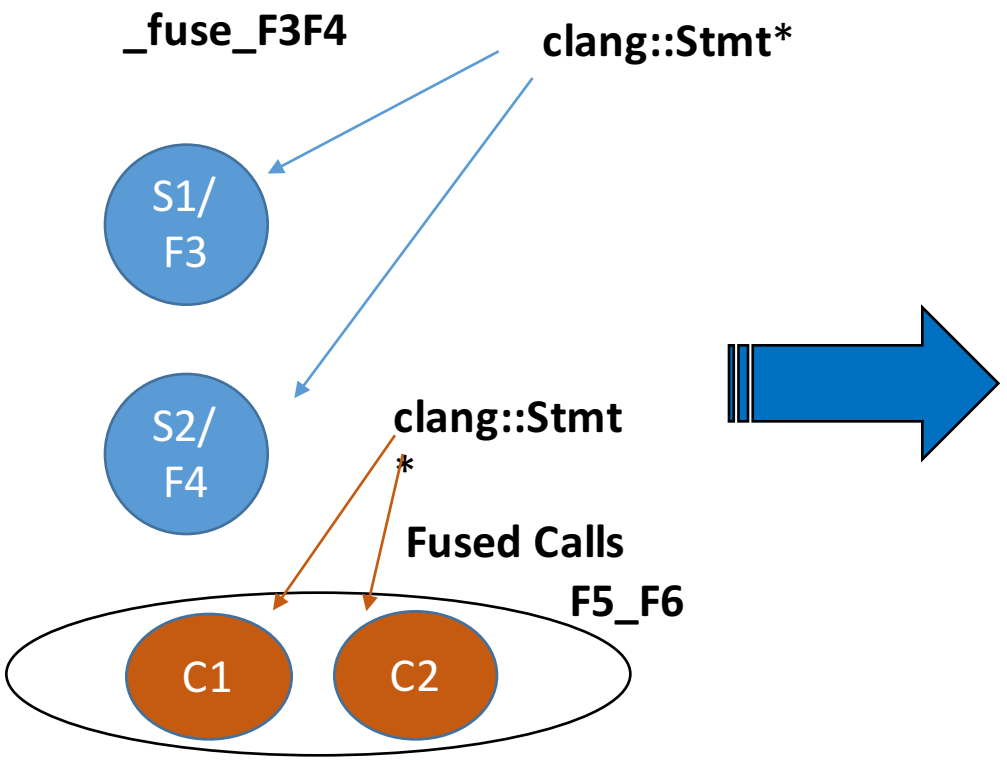
# Code Generation

- Grafter build the fused functions incrementally following a set of rewrite rules while tracking the original source code




```
3  void _fuse__F3F4(TextBox *_r, int active_flags) {
4    TextBox *_r_f0 = (TextBox *)(_r);
5    TextBox *_r_f1 = (TextBox *)(_r);
6    if (active_flags & 0b11) /*call*/ {
7      unsigned int call_flags = 0;
8      call_flags <<= 1;
9      call_flags |= (0b01 & (active_flags >> 1));
10     call_flags <<= 1;
11     call_flags |= (0b01 & (active_flags >> 0));
12     _r_f0->Next->__stub1(call_flags);
13   }
14   if (active_flags & 0b1) {
15     _r_f0->Width = _r_f0->Text.Length;
16     _r_f0->TotalWidth = _r_f0->Next->Width + _r_f0
           ->Width;
17   }
18   if (active_flags & 0b10) {
19     _r_f1->Height = _r_f1->Text.Length * (_r_f1->
           Width / CHAR_WIDTH) + 1;
20     _r_f1->MaxHeight = _r_f1->Height;
21     if (_r_f1->Next->Height > _r_f1->Height) {
22       _r_f1->MaxHeight = _r_f1->Next->Height;
23     }
24   }
25 };
```

# Code generation example




**Parameters**

**Track active traversals**

**Call fused functions**

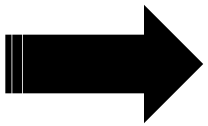
**Computations**

```
3  void _fuse__F3F4(TextBox *_r, int active_flags) {
4    TextBox *_r_f0 = (TextBox *)(_r);
5    TextBox *_r_f1 = (TextBox *)(_r);
6    if (active_flags & 0b11) /*call*/ {
7      unsigned int call_flags = 0;
8      call_flags <<= 1;
9      call_flags |= (0b01 & (active_flags >> 1));
10     call_flags <<= 1;
11     call_flags |= (0b01 & (active_flags >> 0));
12     _r_f0->Next->__stub1(call_flags);
13   }
14   if (active_flags & 0b1) {
15     _r_f0->Width = _r_f0->Text.Length;
16     _r_f0->TotalWidth = _r_f0->Next->Width + _r_f0
           ->Width;
17   }
18   if (active_flags & 0b10) {
19     _r_f1->Height = _r_f1->Text.Length * (_r_f1->
           Width / CHAR_WIDTH) + 1;
20     _r_f1->MaxHeight = _r_f1->Height;
21     if (_r_f1->Next->Height > _r_f1->Height) {
22       _r_f1->MaxHeight = _r_f1->Next->Height;
23     }
24   }
25 };
```

# Code generation example

- Replace original calls with calls to fused functions, and create virtual switches functions as needed.

```
int main(){
  Element *ElementsList = ...;
  ElementsList->computeWidth();
  ElementsList->computeHeight();
}
```



```
void TextBox::__stub1(int active_flags) {
    _fuse__F3F4(this, active_flags);
}
void Group::__stub1(int active_flags) {
    _fuse__F5F6(this, active_flags);
}
void End::__stub1(int active_flags) {
    _fuse__F1F2(this, active_flags);
}
int main() {
    Group *ElementsList;
    //ElementsList->computeWidth();
    //ElementsList->computeHeight();
    ElementsList->__stub1(0b11);
}
```

# It does scale..

We run Grafter on programs with more than 50 functions to be fused and automatically generate programs thousands lines of code that achieve significant speedups.

# Conclusions

- Clang is useful in performing domain specific source to source transformations
- Easy to implement an embedded DSL in C++
- Clang AST is useful in collecting source-level information needed for static analysis
- Clang AST makes it easy to track input program while generating the output program