DiGr: Directed Graph Processing Language

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Final Project Presentation

- What can DiGr do?
  - Represent trees, graphs, walks, (mirrors, knots, etc).
  - Model everything from basic computer science constructs to network-based problems in engineering and industry.
  - Store information in nodes and edges without overhead or hassle.
  - Recursively or iteratively walk and modify directed graphs in user-specified ways.

Introduction to DiGr

- What is the DiGr language / compiler like?
  - Imperative.
  - Compiled. Target language is C++, which is in turn compiled with g++ and linked against the DiGr backend.
  - Statically (and locally) scoped.
  - Specific graph-related objects (nodes, edges, walks) on top of a typed C-like base.
  - Strongly typed.

Primitive types and opts

- Integers, floating point numbers and strings are primitive types.

```
:  this is a comment :
str name = "Ari"!
int age!
age = 22!
flt gpa = 4.0!  :  statements end with a !  :
```

- Opts have no return types, but have `in` (not globally bound) and `out` (in-scope from the program that called them) variables.

```
opt times_two(in int n; out int doubled){
   doubled = n * 2!
}
```

Nodes and edges

- The high-level objects in DiGr are nodes and edges:

```
node n1!
node n2!
n1 -> n2!   :  n1 and n2 are now connected :
```

- Node and edge identifiers are handles. Edges are usually created anonymously:

```
edge e = n1.outedge(0)!
node target = e.innode!
```

Connection contexts and attributes

- Attributes are created as soon as they are referenced or assigned:

```
node city!
city.population = 60000!
print(city.population)!  :  prints 60000 :
print(city.area)!  :  defaults to 0 :
```

- Connection contexts efficiently create graphs, and store the handles to the nodes in an array:

```
node binaryTree[7] = |3->(1->0,2),(5->4,6)| !
```

Crawls and rules

- A `crawl` is an opt run on a node, and can call a `rule` that tells it where to go next.

```
crawl markNode(in int marker) {
    current.mark = marker!
    call!  }
```

- Rules modify the queue of nodes to visit when called:

```
rule followLighterEdge{
    edge e1 = current.outedge(0)!
    edge e2 = current.outedge(1)!
    if (e1.weight < e2.weight)
           { add(e1.child(0))!  }
    else { add(e2.child(0))!  }
}
```

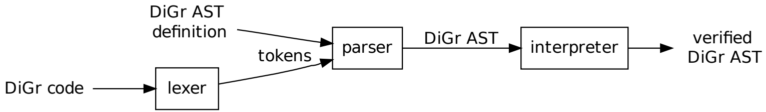
DiGr in one slide

```
crawl printNode() { print(current.id)!  call!  }
:  print the node id and call the rule :

rule preOrder { addByFront(node.id,~,2)!  }
:  add up to two children, smallest id first :

opt main() {
   node tree[5] = |3->(1->0,2),4| !
   tree[0].id = 0!  tree[1].id = 1!  tree[2].id = 2!
   tree[3].id = 3!  tree[4].id = 4!
   printNode() from tree[3] with preOrder!
   :  prints 3 1 0 2 4 :
}
```

Compiler Front End

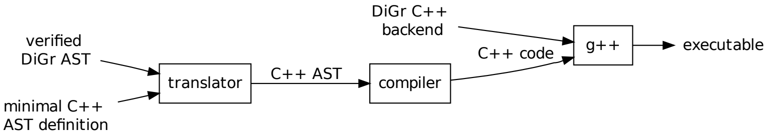


- Scanner turns DiGr program from standard input into tokens. Lexical correctness.
- Parser creates initial AST (nested OCaml tree of typed tuples). Syntactical correctness.
- Interpreter verifies AST. Semantic correctness.

Static Semantic Checking

- The interpreter has several duties:
  - Create global scope for `opt`/`rule`/`crawl` signatures.
  - Create symbol table for all local scopes (inside functions and blocks).
  - Check the scope of all identifiers.
  - Check typing for all statements (recurse into expressions), including assignment, function calls, etc.
- After the front-end stage, intermediate representation of a sensible program (instance of DiGr AST).

Compiler Back End



- C++ AST: stripped-down, holds intermediate representation of C++ program. A few shortcuts, but largely extensible. C++ AST assures *syntactical* correctness of output.
- Translator: converts DiGr AST to C++ AST. Does no semantic checking.
- Compiler: crawls the C++ AST and outputs C++ code.
- g++: turns compiled DiGr code into an executable.

DiGr code pre-compilation

```
rule myrule {
   int n = 0!
   while (n < current.outedges) {
      edge tmp_edge = current.outedge(n)!
      if (tmp_edge.mark == 1) {
         node destination = tmp_edge.innode!
         add(destination)!
      }
      n = n + 1!
   }
}
crawl thecrawl() {
   print (current.id)!
   call!
}
```

DiGr compiler output

```
#include "digr.h"
#include <iostream>
void myrule(DiGrNode *current, deque<DiGrNode*> *returnQueue) {
int n = 0 ;
while(n < current->OutEdges())
{DiGrEdge *tmp_edge = current->getOutEdge(n);
if(tmp_edge->getAttribute("mark") == 1 )
{DiGrNode *destination = tmp_edge->inNode();
returnQueue->push_back(destination);
}
else{}
n=n + 1 ;
}
}
void thecrawl(DiGrNode *current, void (*rule)(DiGrNode*, deque<DiGrNode*>*)) {
deque<DiGrNode*> *queue = new deque<DiGrNode*>();
queue->push_back(current);
do {
current=queue->front();
queue->pop_front();
std::cout << current->getAttribute("id") << std::endl;
rule(current, queue);
} while (queue->size() > 0 );
}
```

DiGr Test Plan

- For each test program, we have a *gold standard* that execution should output. Every build, we compile and execute all tests and compare output with the gold standard.
- Test atomic DiGr elements from low-level (basic types, arithmetic, function calls, etc.) to high-level (graphs, attributes, connection contexts, etc.).
- Test programs which integrate a wide cross-section of features.
- Test errors at compilation (really, the interpret stage), and at run-time.