Damo

A language for symbolic functions

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I. Introduction

Why...

CORE FEATURES

- Scripting language
- Symbolic expressions
- Standard library for symbolic function evaluation, automatic differentiation

MOTIVATION

- Ease of development for applications requiring automatic differentiation
- Useful for many kinds of machine learning, such as SGD algorithm for neural networks
- Historical note:
  - Damo was child of Theano – a popular Python deep learning library

II. Project Management
Responsibilities, lessons learned

EVERYONE BECOMES A DEVELOPER

Abhiroop — Built SAST, semantic checking and tests

Ian — Implemented parser, standard library and tests

Hari — Implemented codegen and tests

Alan — Took the worst classes of his life this semester

LESSONS LEARNED

- Iterative development makes life easier
- Specialization is helpful, but dangerous
- Realistic deadlines are necessary
- Never assume that something works

III. The Damo Language

Speaking our dialect

SYNTAX BASICS

```
// Single line comment

/*
   Multiline
   comment
*/


// VARIABLE DECLARATION
int i;
int j = 1;
```

```
/*
OPERATORS
+ - * / ^ _ %
and or not
< > <= >= == !=

TYPES
int
num
bool
string
symbol
*/
```

SIMPLE PROGRAMS

```
print(“Hello world”);

// FUNCTION DECLARATION
def sayHello(string name) : void {
     print(“Hello, “);
     print(name);
}

sayHello(“Stephen”);
```

```
num a;
num b;
num c;

a = 1;
b = 2.0;
c = a * b;

print_num(c);
```

CONTROL FLOW

```
// C-like loops

int i;

print("Going up");
for (i = 0; i < 10; i = i + 1){
     print_int(i);
}

print("Going down");
while (i > 0){
     print_int(i);
     i = i - 1;
}
```

```
// C-like if-elseif-else statements

if (i < 0){
     print("i less than 0");
}
elseif (i < 10){
     print("i less than 10");
}
else {
     print("i greater than 10");
}
```

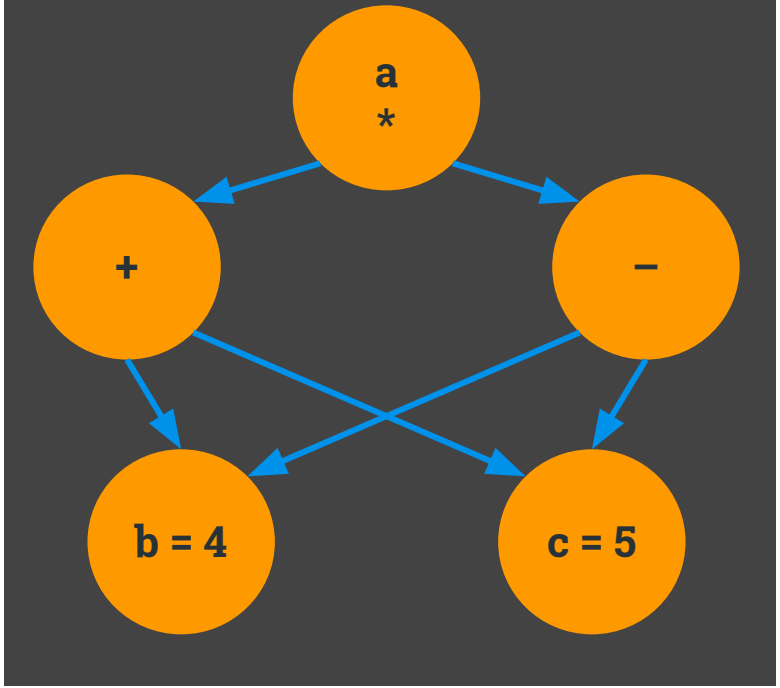
SYMBOLIC EXPRESSIONS

```
// Declare symbols
symbol a;
symbol b;
symbol c;

// Set symbolic expression
a = b + c;
a = a * (b - c);

// Set symbols to constant values
b = 4;
c = 5;
```

```
// DEPENDENCY GRAPH
```



THE STANDARD LIBRARY

```
// Function evaluation
symbol a; symbol b; symbol c;

a = b * c;
b = 4;
c = 5;

num result = eval(a);
num deriv = partialDerivative(a, b);
```

IV. How it works
Implementation details

OUR COMPILATION PIPELINE

Source code	Program written in Damo
Linked with stdlib	Standard library prepended
Symbols	Scanner
AST	Parser
SAST	Semantic checking
LLVM	Codegen
Executable	C compiler: links with C code

ABSTRACT SYNTAX TREE

- A Damo program is a list of variable declarations, function declarations, and statements
- Arbitrary ordering
- Semantic checking verifies proper usage of variables and functions

HEAP ALLOCATED SYMBOLS

- Invoke C functions to allocate heap memory

```
symbol_malloc = Llvm.declare_function “createSymbol” (Llvm.function_type
symbol_t [| |] the_module
...
A.Symbol -> let global_variable = L.build_call symbol_malloc [| |] “symbolmal”
builder in ignore(L.build_store global_variable s_v builder);
```

THE SYMBOL STRUCT

- Underlying C struct represents symbol type

```
struct symbol {
      symbol *left;
      symbol *right;
      int isConstant;
      int isInitialized;
      double value;
};
```

LINKING WITH C CODE

- Makefile builds symbol.c, a library we wrote to handle routines relating to symbols
  - Heap memory allocation
  - Accessor, mutator functions
- Damo executables are linked with C standard library, and symbol.o

V. Testing

It works, we promise

UNIT AND INTEGRATION TESTS

- We tested for every feature of the Damo language
  - Operators
  - Functions
  - Global variables
  - Standard library functions
  - Etc.

THE ULTIMATE TEST

- Showing off in our demo – a big integration test

Let’s demo it!