

[M]<sup>s</sup>

# 挑战与未来



ZOMI 酱

Building a better connected world



[www.mindspore.cn](http://www.mindspore.cn)

# 关于本课程

## 1. 课程背景

- AI框架中自动微分的重要性

## 2. 课程内容

- 微分基本概念：数值微分 - 符号微分 - 自动微分
- 自动微分模式：前向微分 – 后向微分 – 雅克比原理
- 具体实现方式：表达式或图 – 操作符重载OO – 源码转换 AST
- MindSpore实现：基于图表示的源码转换Graph Base AST
- 自动微分的挑战与未来

# AD Challenge - Ease of use

[M]<sup>s</sup>

- 理想中的自动微分是对**数学表达**的分  
解、微分和组合过程
- 实际中的自动微分是对**程序表达**的分  
解、微分和组合过程

$$\begin{aligned}l_1 &= x \\l_{n+1} &= 4l_n(1 - l_1) \\f(x) &= l_4 = 64x(1 - x)(1 - 2x)^2(1 - 8x + 8x^2)^2\end{aligned}$$



```
f(x):  
    v = x  
    for i = 1 to 3:  
        v = 4 * v * (1 - v)  
    return v
```

# AD Challenge - Ease of use (I)

[M]<sup>s</sup>

## 控制流表达问题

```
 $l_1 = x$ 
 $l_{n+1} = 4l_n(1 - l_1)$ 
 $f(x) = l_4 = 64x(1 - x)(1 - 2x)^2(1 - 8x + 8x^2)^2$ 
```



```
f(x):
    v = x
    for i = 1 to 3:
        v = 4 * v * (1 - v)
    return v
```

识别程序表达中用于计算控制流的运算部分，并将其排除在微分过程外

## 复杂数据类型

```
 $dx = x$ 
 $l_{n+1} = 4l_n(1 - l_1)$ 
 $f(x) = l_4 = 64x(1 - x)(1 - 2x)^2(1 - 8x + 8x^2)^2$ 
```



```
<aexp> ::= NUMBER | STRING | VAR | BOOLEAN | PRIMOP
Python ::= [List, Enum, Tuple, Dict, DefaultDict]
C++ ::= [size_t, whcar_t, enum, struct , STL::list]
```

# AD Challenge - Ease of use (II)

[M]<sup>s</sup>

## 语言特性

- 多态、异常处理、调试、IO处理、继承等

## 需求重写

- 物理模拟、游戏引擎、气候模拟有DSL属性

# AD Challenge - Performance

[M]<sup>s</sup>

## 程序与微分表达

$$f = x^3$$

$$dx = 3 * x^2$$

```
def fun(x):
    t = x * x * x
    return t
```

```
def dfun(x):
    dx = 3 * x * x
    return dx
```

```
def fun(x):
    t = x * x
    v = x * t
    dx = 3 * t
    return v, dx
```

# AD Challenge - Performance

[M]<sup>s</sup>

## 额外中间变量

$$\bar{v}_i = \frac{\partial y_i}{\partial v_i}$$

### Forward Primal Trace

$$\begin{array}{ll} v_{-1} = x_1 & = 2 \\ v_0 = x_2 & = 5 \end{array}$$

$$v_1 = \ln v_{-1} = \ln 2$$

$$v_2 = v_{-1} \times v_0 = 2 \times 5$$

$$v_3 = \sin v_0 = \sin 5$$

$$v_4 = v_1 + v_2 = 0.693 + 10$$

$$v_5 = v_4 - v_3 = 10.693 + 0.959$$

$$y = v_5 = 11.652$$

### Reverse Adjoint (Derivative) Trace

$$\begin{array}{lll} \bar{x}_1 = \bar{v}_{-1} & & = 5.5 \\ \bar{x}_2 = \bar{v}_0 & & = 1.716 \end{array}$$

$$\bar{v}_{-1} = \bar{v}_{-1} + \bar{v}_1 \frac{\partial v_1}{\partial v_{-1}} = \bar{v}_{-1} + \bar{v}_1 / v_{-1} = 5.5$$

$$\bar{v}_0 = \bar{v}_0 + \bar{v}_2 \frac{\partial v_2}{\partial v_0} = \bar{v}_0 + \bar{v}_2 \times v_{-1} = 1.716$$

$$\bar{v}_{-1} = \bar{v}_2 \frac{\partial v_2}{\partial v_{-1}} = \bar{v}_2 \times v_0 = 5$$

$$\bar{v}_0 = \bar{v}_3 \frac{\partial v_3}{\partial v_0} = \bar{v}_3 \times \cos v_0 = -0.284$$

$$\bar{v}_2 = \bar{v}_4 \frac{\partial v_4}{\partial v_2} = \bar{v}_4 \times 1 = 1$$

$$\bar{v}_1 = \bar{v}_4 \frac{\partial v_4}{\partial v_1} = \bar{v}_4 \times 1 = 1$$

$$\bar{v}_3 = \bar{v}_5 \frac{\partial v_5}{\partial v_3} = \bar{v}_5 \times (-1) = -1$$

$$\bar{v}_4 = \bar{v}_5 \frac{\partial v_5}{\partial v_4} = \bar{v}_5 \times 1 = 1$$

$$\bar{v}_5 = \bar{y} = 1$$

## 额外中间变量

二阶微分方程的一般形式：

$$F(x, y, y', y'') = 0$$

其中， $x$ 是自变量， $y$ 是未知函数， $y'$ 是 $y$ 的一阶导数， $y''$ 是 $y$ 的二阶导数。

$$\frac{d^2y}{dx^2} = \frac{d}{dy} \left( \frac{dy}{dx} \left( \frac{dx}{x} \right) \right)$$

# AD Challenge - Performance

[M]<sup>s</sup>

## 重计算与编译优化

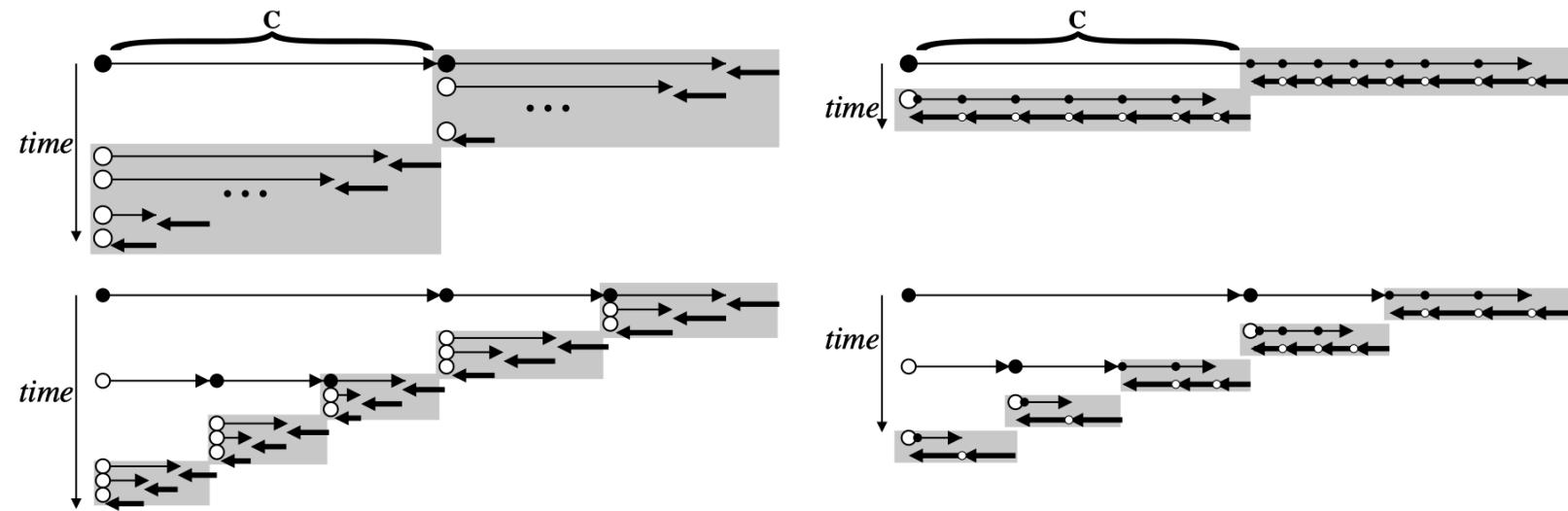


Figure 3: Checkpointing with the Recompute-All (*left*) and Store-All (*right*) approaches. The shaded areas reproduce the basic pattern of the chosen approach. *top*: single checkpointing, *bottom* nested checkpointing.

## 可微编程

将自动微分技术与语言设计、编译器 / 解释器甚至 IDE 等工具链等深度融合，将微分作为语言中 first-class feature

# Conclusion

[M]<sup>s</sup>

1. 自动微分挑战主要集中在易用性和性能两方面
2. 易用性受限于控制流、数据类型等语言特性以外，还受限于领域需求
3. 性能主要以程序表达与微分表达结合，编译，甚至高阶微分等引起



BUILDING A BETTER CONNECTED WORLD

THANK YOU

TEAMS

Copyright©2014 Huawei Technologies Co., Ltd. All Rights Reserved.

The information in this document may contain predictive statements including, without limitation, statements regarding the future financial and operating results, future product portfolio, new technology, etc. There are a number of factors that could cause actual results and developments to differ materially from those expressed or implied in the predictive statements. Therefore, such information is provided for reference purpose only and constitutes neither an offer nor an acceptance. Huawei may change the information at any time without notice.