22nd International Symposium on Trends in Functional Programming

17th-19th February, 2021 Online

Dimensional Analysis for Multidimensional Dataflow Programming

Bill Wadge & Monem Shennat

wwadge@uvic.ca ashennat@uvic.ca

lambda DAλS

16-19 FEBRUARY 2021
VIRTUAL EVENT

Introduction

Multidimensional Data

Dimensional Analysis Example

Main Objective

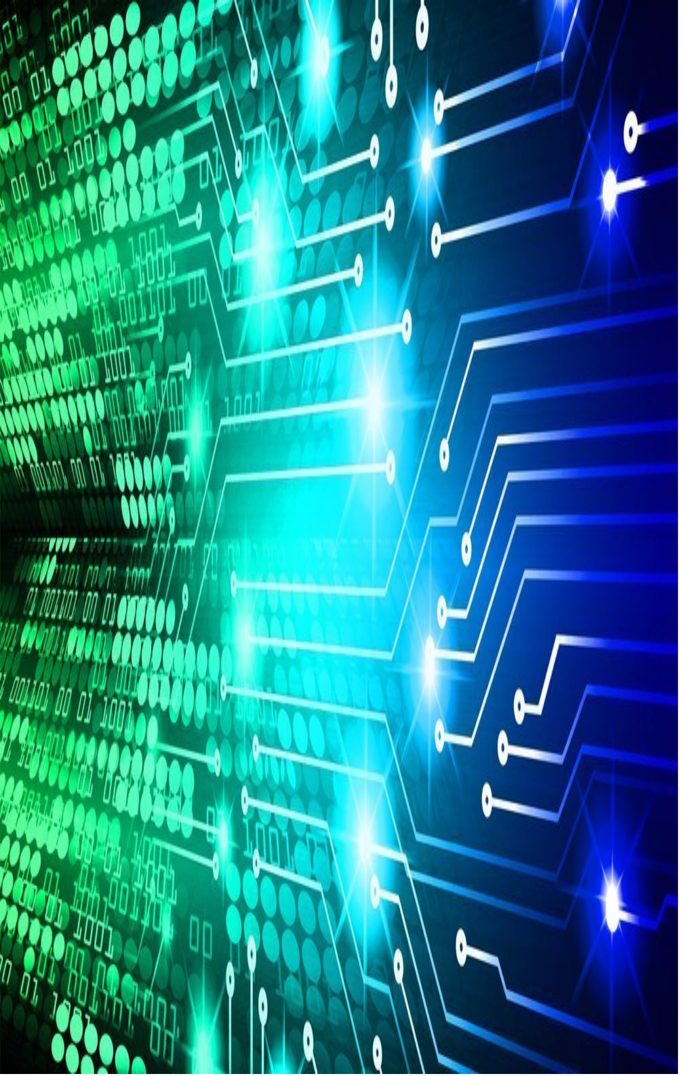
Data Flow Operators

Dimensional Analysis Algorithms

Conclusion

Significance

lambda
DAλS
16-19 FEBRUARY 2021
VIRTUAL EVENT



INTRODUCTION

Dataflow Programming

Is programming in functional language in which every data object is a stream. Lucid is our prime example.

Statements in Lucid

The statement of Lucid program are equations specifying the transformations to be applied to streams, e.g. S = rsum(X).

lambda DAΛS
16–19 FEBRUARY 2021
VIRTUAL EVENT

CONTINUED…

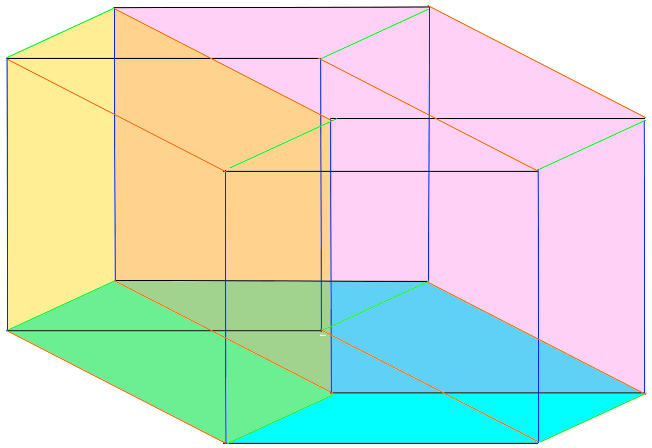
Multidimensional Data

There are numerous Multidimensional data base (MDB) systems as well as OLAP systems, which are also based on a multidimensional model.

GLU and Dimensionality

GLU was a dialect of Lucid that allowed multiple dimensions. It's DA was primitive.

GENERAL EXAMPLE OF DIMENSIONAL ANALYSIS



6 Dimensions
- Detector dimension & Field of View
- Bit depth
- Time
- Patient
- Date

X-Ray Dimensions

The measurements are represented in one to four possible values start with the first dataset.

lambda DAYS
16-19 FEBRUARY 2021
VIRTUAL EVENT

MAIN OBJECTIVE

Our goal is to create an algorithm for Dimensional Analysis of a multidimensional dialect of the data flow language Lucid that allows us to calculate the dimensionality of program variables, and to exclude irrelevant dimensions.

lambda DAΛS
16–19 FEBRUARY 2021
VIRTUAL EVENT

THE BASIC OPERATORS

FIRST

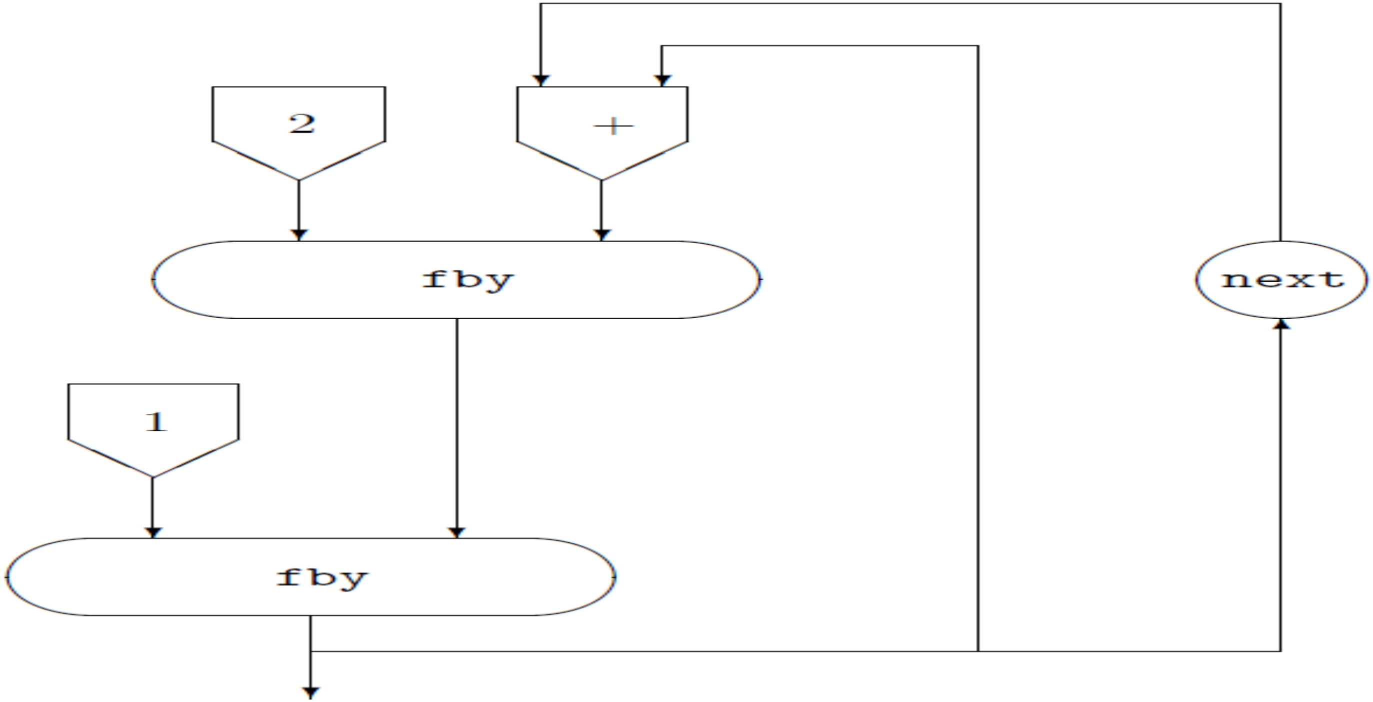
NEXT

ASA

FBY

lambda DAλS
16–19 FEBRUARY 2021
VIRTUAL EVENT

SIMPLE DATA FLOW NETWORK



LET'S REVIEW SOME CONCEPTS

First & Next

First send on the first item in its input stream and surpasses the rest.

Next skips the first and passes on the rest

FBY

The output of this operator is the first component of its first input followed by its entire second input

ASA

The value of the first argument has when the second argument first becomes true

lambda DAλS

16-19 FEBRUARY 2021
VIRTUAL EVENT

“ DIMENSIONAL ANALAYSIS ALGORITHMS

Time Dimension {t}

↓

Space and Time Dimensions {s, t}

↓

Multiple Dimensions {s, t, h, v, z, …}

ALGORITHM FOR ONE DIMENSION “TIME”

a = b + c

m = i + 1

d = 3

i = 1 fby m

b = first j

j = 1 fby k

c = next i

CONTINUE...

d = 3

b = first j

a = b + c

c = next i

m = i + 1

j = 1 fby k

i = 1 fby m

ALGORITHM FOR TWO DIMENSIONS "TIME & SPACE"

The algorithm for time and space is slightly more complex. Instead of accumulating.

A single set we accumulate a table that assigns to each variable a subset of {s, t}.

Subset is the estimated dimensionality of the variable, i.e. the set of dimensions relevant to the value of the variable.

lambda DAλS
16-19 FEBRUARY 2021
VIRTUAL EVENT

CONTINUED...

P = 8

Q = X sby T

T = P fby Q

V = T + Q

X = first Q

lambda DAλS
16–19 FEBRUARY 2021
VIRTUAL EVENT

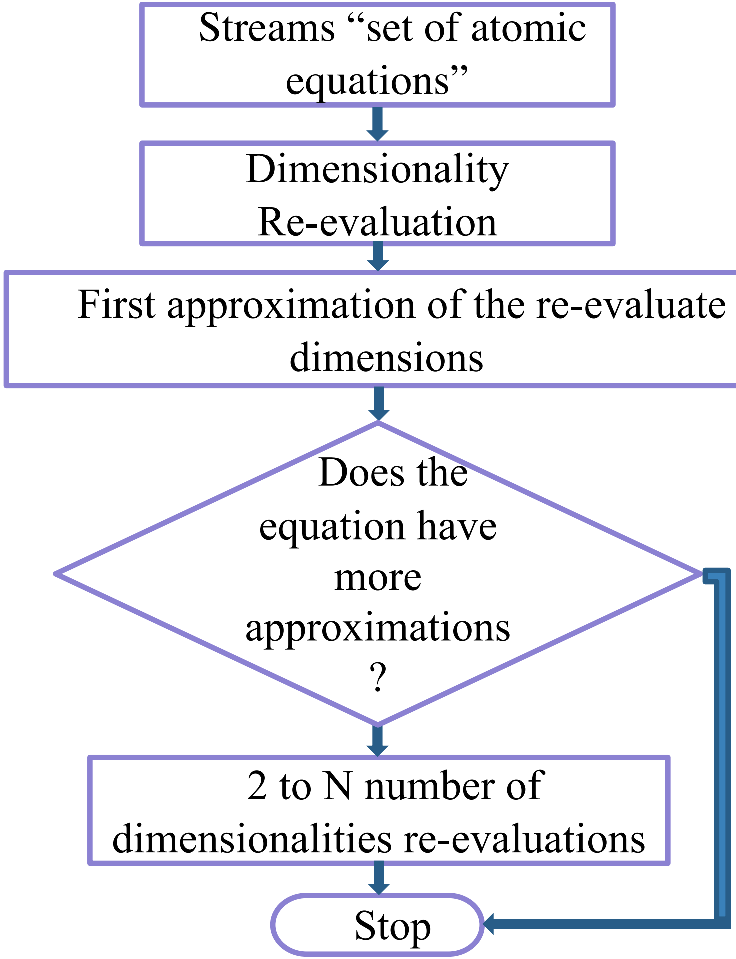
ALGORITHM FOR MULTIPLE DIMENSIONS

Unlimited sets can be accumulated in a table which assigns to each variable a set of dimensions based on how many times this variable will be re-evaluated

lambda DAλS

16-19 FEBRUARY 2021
VIRTUAL EVENT

CONTINUED...



Streams “set of atomic equations”
Dimensionality Re-evaluation
First approximation of the re-evaluate dimensions
Does the equation have more approximations ?
2 to N number of dimensionalities re-evaluations
Stop

CONTINUED…

Set of 'atomic' Eqs	Dimensionalities Re-evaluation	First Appro	Second	Third	Forth	Fifth
Y = H fby.c V	Y's dimensionality	{ }	{c}	{c, m}	{c, m, k}	
X = next.c Y	X's dimensionality	{ }	{ }	{c}	{c, m}	{c, m, k}
H = X fby.m Y	V's dimensionality	{}	{m}	{c, m}	{c, m}	{c, m, k}
W = X asa.c Y	W's dimensionality	{}	{}	{}	{m}	{m, k}
R = Y fby.k X	R's dimensionality	{}	{k}	{k, c}	{k, c, m}	

lambda DAλS
16-19 FEBRUARY 2021
VIRTUAL EVENT

CONCLUSION

We have algorithms to estimate the dimensionality of programs with one, two, and multiple dimensions. What remains is to analyze programs with user-defined transformations, e.g.

rsum(X) = S where S = first X fby S + next X

lambda DAλS

16-19 FEBRUARY 2021
VIRTUAL EVENT

SIGNIFICANCE

Our DA algorithm will make possible the efficient implementation of multidimensional Lucid. Also, tools or platforms such as TensorFlow needs to know which dimensions are relevant, and currently this is the user’s responsibility.

lambda DAΛS
16-19 FEBRUARY 2021
VIRTUAL EVENT

THANK YOU!

lambda DAΛS
16-19 FEBRUARY 2021
VIRTUAL EVENT