The Stencil Pattern

A Short Introduction

Joseph Kehoe[1]

[1]Department of Computing and Networking
Institute of Technology Carlow

CDD101, 2017

Table of Contents

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Table of Contents

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Definition

- The Stencil pattern is a special case of the Map pattern.
- The function is applied to every element in the set concurrently as with the map.
- But the imnput to the elemental function includes not just the current instance but also other elements in its local neighbourhood
- The output is a function of some neighbouring elements in an input collection.
- The function contains dependencies on its surrounding elements

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Related Patterns

- Stencil is a specific case of a Map
- The map elemental functions has no dependencies but the stencil has
- The stencil has read dependencies
- It is a very common pattern in the real world
- Can be one, two or N dimensional (usually represented as a grid (matrix)

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Table of Contents

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Details

- Neighbourhood is specified using a set of fixed offsets relative to the output position
  - Von Neuman neighbourhood (North, South, east and West)
  - Moore Neighbourhood (8 compass points NE,NW,SE,SW,N,S,E,W)
- Show these as offsets on 1,2 and 3D grids!
- Grid can be sparse or dense
  - There are special ways of handling sparse matrices

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Table of Contents

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Usage of Stencils

- Image and Signal Processing (medical, satelite and vision)
- Partial Differential Equation (PDE) solvers over regular grids
- Seismic Simulations (especially oil and gas)
- Weather Simulation

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Serial Implementation

Basic Code

```
void stencil(int dim,float in[], float out[],
                              func f,int size)
{
        float neighbours[size];
        for (int i=0; i < dim; ++i)
        {
                neighbours=calcNeighbours(in,i,size);
                out[i]=f(neighbours);
        }
}
```

- calcNeighbours depends on neighbourhood type

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Table of Contents

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Cache Behaviour

- Cache behaviour is very important
- The grid is usually divided into tiles
- Each thread computes all elements in one (or more) tile(s)
  - Each tile is mostly self contained but elements at the edge of one tile will need to read elements in the adjacent tiles
  - This is handled using **ghost** tiles that is tiles we need to read from another tile but do not update
  - Set of ghost tiles known as **halo**
- Each tile will need to communicate with adjacent tiles (why?)
- Shape of tiles will affect cache interaction

Tile Shape

- Grid usually stored in array
- When are two array locations stored beside each other in memory?
  - Depends on programming language (Fortran vs C)
- Optimising tiles for stencils sometimes known as **strip-mining**
  - Strips are a multiple of cache line width (to prevent false sharing - what is this?)

Table of Contents

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Recurrances

- Recurrances are neighbourhoods of **outputs**
- Instances in a recurrance can depend on values computed by other instances
- In serial code this appears as loop carried dependencies in which iterations of the loop depend on previous iterations

Even though the loop iterations are not independent it is still possible to partallelize the loop

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster

Example Recurrance

- Assume a grid (array) of data
- Each element a[i][k] depends on the output of the value to its left and above it
- That is, a[i][k] depends on a[i-1][k] and a[i][k-1]
- Show this on a diagram
- This can be paralellised using a **hyperplane**
- This can be difficult to implement

Example Recurrance

```
void recurrance(int xdim,int ydim,
                float in[xdim][ydim],
                float out[xdim][ydim])
{
  float neighbours[size];
  for (int i=0; i < xdim; ++i)
  {
    for(int k=0; k<ydim;++k)
    {
      out[i,k]=f(in[i,k],out[i-i][k],out[i][k-1]);
    }
  }
}
```

Institiúid Teicneolaíochta Cheatharlach
INSTITUTE of TECHNOLOGY CARLOW
At the Heart of South Leinster