

SubSystem in Alpha

In this tutorial, we will present how to write structured alpha programs with subsystems, and we will present the associated transformations.

Syntax of Use Equation (without extension domain)

Let us assume that we want to compute the mean of the values of a vector. It is feasible through the following Alpha system:

```
affine mean {N | N>0}
input
  float A {k | 0<=k<N};
output
  float C {||};
local
  float temp {||};
let
  temp = reduce(+, [k], A[k]);
  C = temp / N;
.
```

However, let us assume that you already have another Alpha system which computes the sum of the elements of a vector. It is possible to use this affine system (instead of rewriting its equation in the main system), by calling it through a **use equation**:

```
affine sum {P| P>0}  // Computes the sum of the elements of a vector of size
P
input
  float vect {i | 0<=i<P };
output
  float Res;
let
  Res = reduce(+, [k], vect[k]);
.

affine mean {N | N>0}
input
  float A {k | 0<=k<N};
output
  float C {||};
local
  float temp {||};
let
  use sum[N] (A) returns (temp);           // Compute "temp" using the system
```

```
"sum"  
  C = temp / N;  
.
```

The system “mean” is calling the system “sum” (which is called a subsystem). The subsystem is called with the parameter “N” and the input “A”. After doing its computation, the result of “sum” will be stored inside the local variable “temp”.

In general, the syntax of a use equation is the following:

```
use subsystem_name[list of parameters] (list of input expressions) returns  
(list of output variables);
```

If your subsystem has several parameters/inputs/outputs, you have to provide them in the order in which they are declared.

Extension domain

Let us assume that you have a system which computes a dot product of two vectors:

```
affine dotProduct {N | N>0}  
input  
  float v1 {k | 0<=k<N};  
  float v2 {k | 0<=k<N};  
output  
  float Res {||};  
let  
  Res = reduce(+, [k], v1[k]*v2[k]);  
.
```

If you want to compute a matrix vector multiplication using this affine system, you will need to instantiate it once per rows of the matrix. Thus, you will need a parametrised number of call to the “dotProduct” system.

It is possible to do it by using an extension domain:

```
affine dotProduct {N | N>0}  
input  
  float v1 {k | 0<=k<N};  
  float v2 {k | 0<=k<N};  
output  
  float Res {||};  
let  
  Res = reduce(+, [k], v1[k]*v2[k]);  
.
```

```

affine matrixVectorProduct {R,S | (R,S)>0}
input
  float mat {i,j | 0<=i<R && 0<=j<S };
  float vect {j | 0<=j<S};
output
  float vectRes {i | 0<=i<R};
let
  use {k | 0<=k<R} dotProduct[R] ( (k,j->k,j)@mat, (k,j->j)@vect) returns
(vectRes);
.

```

The set “ $\{k \mid 0 \leq k < R\}$ ” before the subsystem name is called the **extension domain**. We are calling the system “dotProduct” once, for each instance of “k” in the extension domain. We can use the indexes of the extension domain to parametrize the parameters, inputs given to the subsystem and the outputs computed by the subsystem:

1. the indexes can be used to specify the parameters (ex: “R+k”)
2. the first dimensions of the input expressions correspond to the dimensions of the extension domain. For a given subsystem call kInst, the corresponding input sent is the one where the first dimensions are set to “kInst” (ex: in the previous example, the third call to “dotProduct” will obtain “(j→3,j)@mat” and “(j→j)@vect” as inputs).
3. the first dimensions of the output variables correspond to the dimensions of the extension domain. All the results from every subsystem call are gathered inside common variables (ex: “vectRes[3]” is the output of the third instance of “dotProduct”)

Apart from the compatibility of dimensions, the input expressions must be defined at least on the points asked by the subsystem, and the output variable must be defined on a subset of the domain of the subsystem output.

Transformations involving subsystems

InlineSubSystem: Inline the equations of a subsystem inside the affine system calling it. The use equation of the main system is replaced by the equations of the subsystem (which are adapted), and new local variables are added.

OutlineSubSystem: Given a list of equations of an affine system, outline them inside a new system and replace these equation by a use equation. The current version (July 2014) do not allow to specify an extension domain, however this is a work in progress.

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