Multidimensional Dataflow in Ptolemy

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Motivation

- Dataflow models processing arrays of data.
- ArrayOL formalism for multidimensional dataflow.
- Coarse and fine grain parallelization.
- SpearDE, developed by Thales.

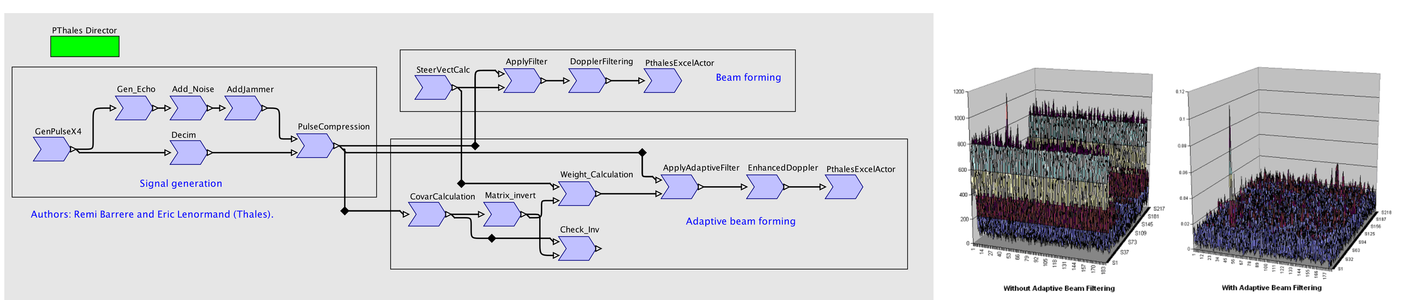


Figure: A Pthales model for adaptive beam-forming

Goals

- Develop the Pthales domain for multidimensional dataflow.
  - Use the Ptolemy platform as a basis for research in multidimensional dataflow models in the context of heterogenous system semantics, code generation, scheduling techniques, and the semantics of time.
- Implement the semantics of SpearDE and ArrayOL in Pthales.
- Formulate semantics for static and dynamic models.
- Integrate the Pthales domain with other models of computation.
- Develop code generation and hardware mapping.
- Experiment with temporal semantics in Pthales.

A Pthales Model

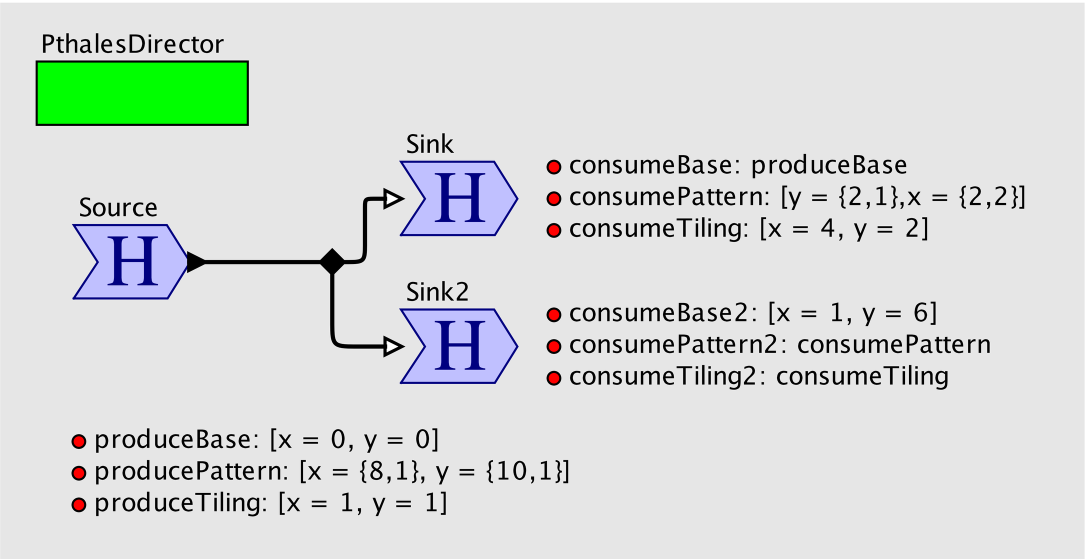


Figure: A simple Pthales model.

Pthales Port Semantics

At each port, Pthales actors produce and consume patterns of data tiled within arrays. Ports in the model are given a set of array data parameters of the following form:

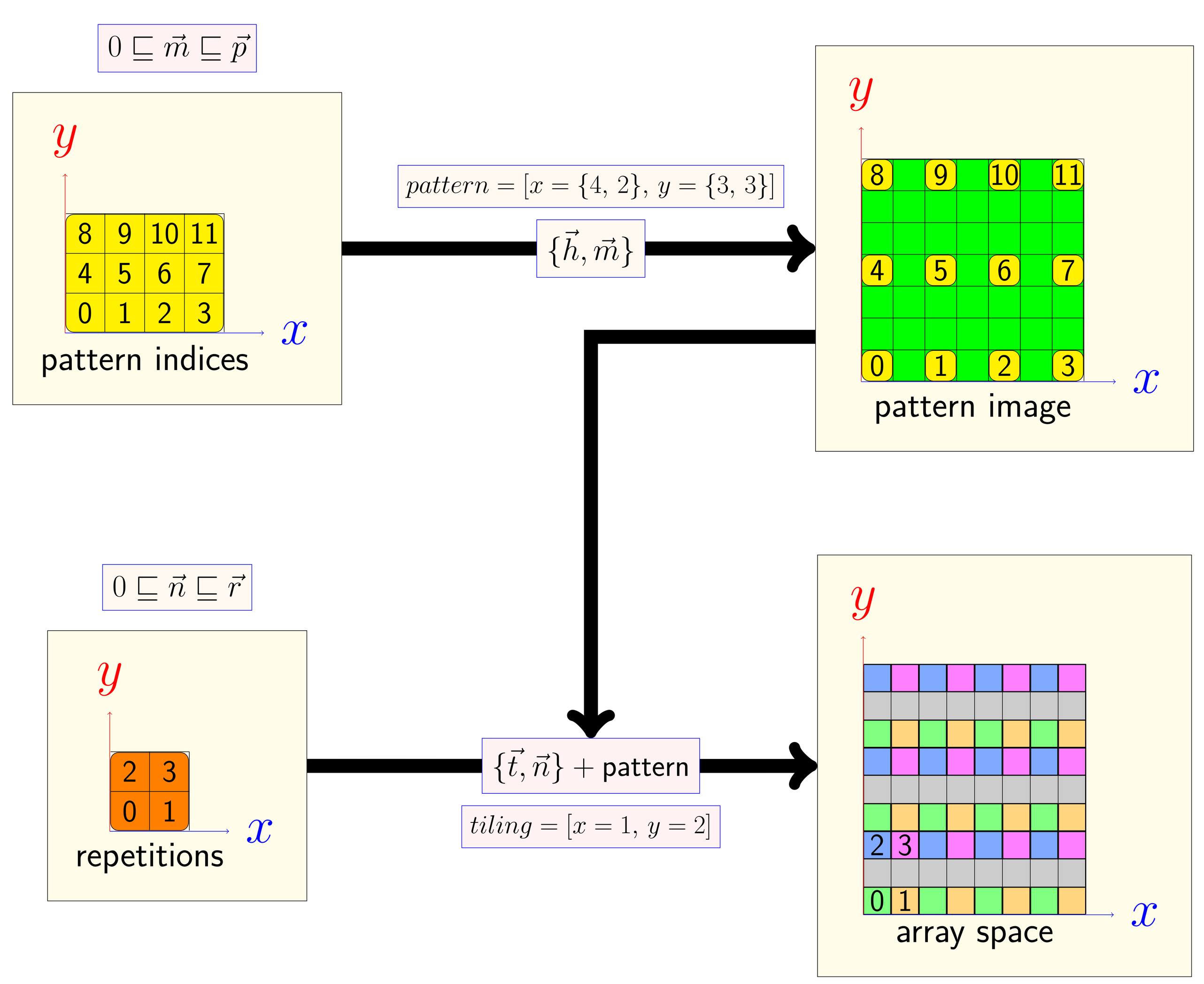
$$\textbf{parameter} = [a = x_a,\ b = x_b, \dots]$$

where $(a, b, \dots)$ are names and $(x_a, x_b, \dots)$ are associated data.

Parameter	Form x_n	Meaning
base	b_n	b_n - base coordinate
pattern	$\{p_n,\ h_n\}$	p_n - pattern dimension, h_n - pattern step size
tiling	t_n	t_n - tiling step size
size	s_n	s_n - array dimension
repetitions	r_n	r_n - pattern repetitions

[if p_n is substituted for $\{p_n,\ h_n\}$, h_n defaults to 1]

Illustration



Computing Parameters

A parameter set $(\vec{b}, \vec{p}, \vec{h}, \vec{t}, \vec{s}, \vec{r})$ is overdetermined with the constraint that the repetitions must fill the array as much as possible. $\vec{s}$ can be calculated from $\vec{r}$:

$$\vec{s} \sqsupseteq \vec{b} + \{\vec{t},\ \vec{r} - \vec{1}\} + \{\vec{p},\ \vec{h} - \vec{1}\} + \vec{1}$$

where $\{\vec{a}, \vec{b}\}$ denotes point-wise multiplication.
If $\vec{s}$ is given, $\vec{r}$ can be calculated:

$$\vec{r} \sqsubseteq \{\vec{s} - \vec{b} - \vec{1} - \{\vec{p},\ \vec{h} - \vec{1}\} - \vec{t},\ \vec{t}^{-1}\}$$

the greatest $\vec{r}$ satisfying this condition being:

$$\vec{r} = \lfloor \{\vec{s} - \vec{b} - \vec{1} - \{\vec{p},\ \vec{h} - \vec{1}\} - \vec{t},\ \vec{t}^{-1}\} \rfloor$$

Dynamic Pthales

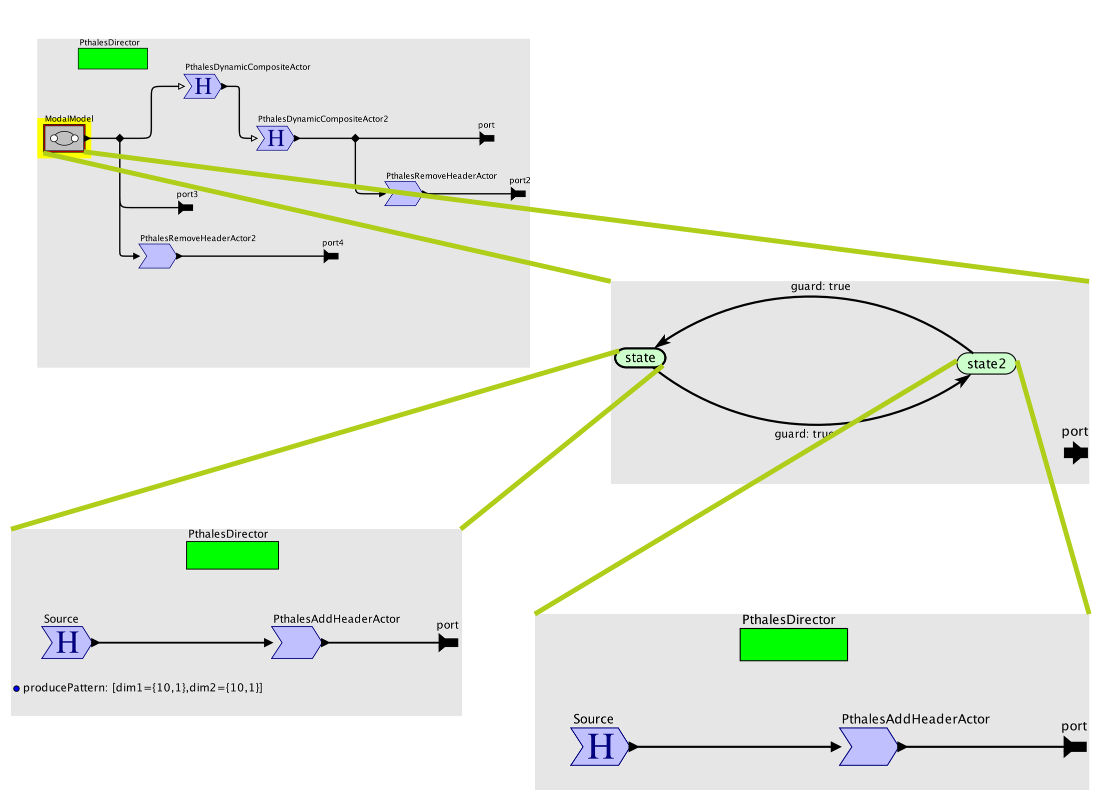


Figure: A modal Pthales model.

Modal Pthales

- Static Pthales extended with modal models.
- Parameter Dynamic Pthales allowing $\vec{s}$ to vary with data and $\vec{r}$ to be recomputed.

Parameter-Dynamic Pthales

- Parameters such as data sizes, tiling, pattern, repetitions, are dynamically changed.
- Parameter changes are propagated throughout models using header information included in data packets.

Future Work

- Embedding Pthales semantics into Process Networks.
- Expanding specification language to include expressions as parameters.
- Automatic generation of parameters from other specifications.
- Code generation for multicore platforms.
- Pipelined scheduling techniques.
- Hierarchical characterization of dynamic semantics:
  - How can different forms of dynamic multidimensional semantics be interrelated or included in one another?
  - What is the relationship between scenario-based and modal model approaches to dynamic semantics?