Higher-Order Functions

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Higher-Order Functions

HOFs are functions that take functions as arguments and return functions. For example

map f

returns a function that applies function f to elements of a list. In a typical functional language (Haskell):

$$\text{scan}\ (f, \mathit{init}, \perp) = \mathit{init}$$

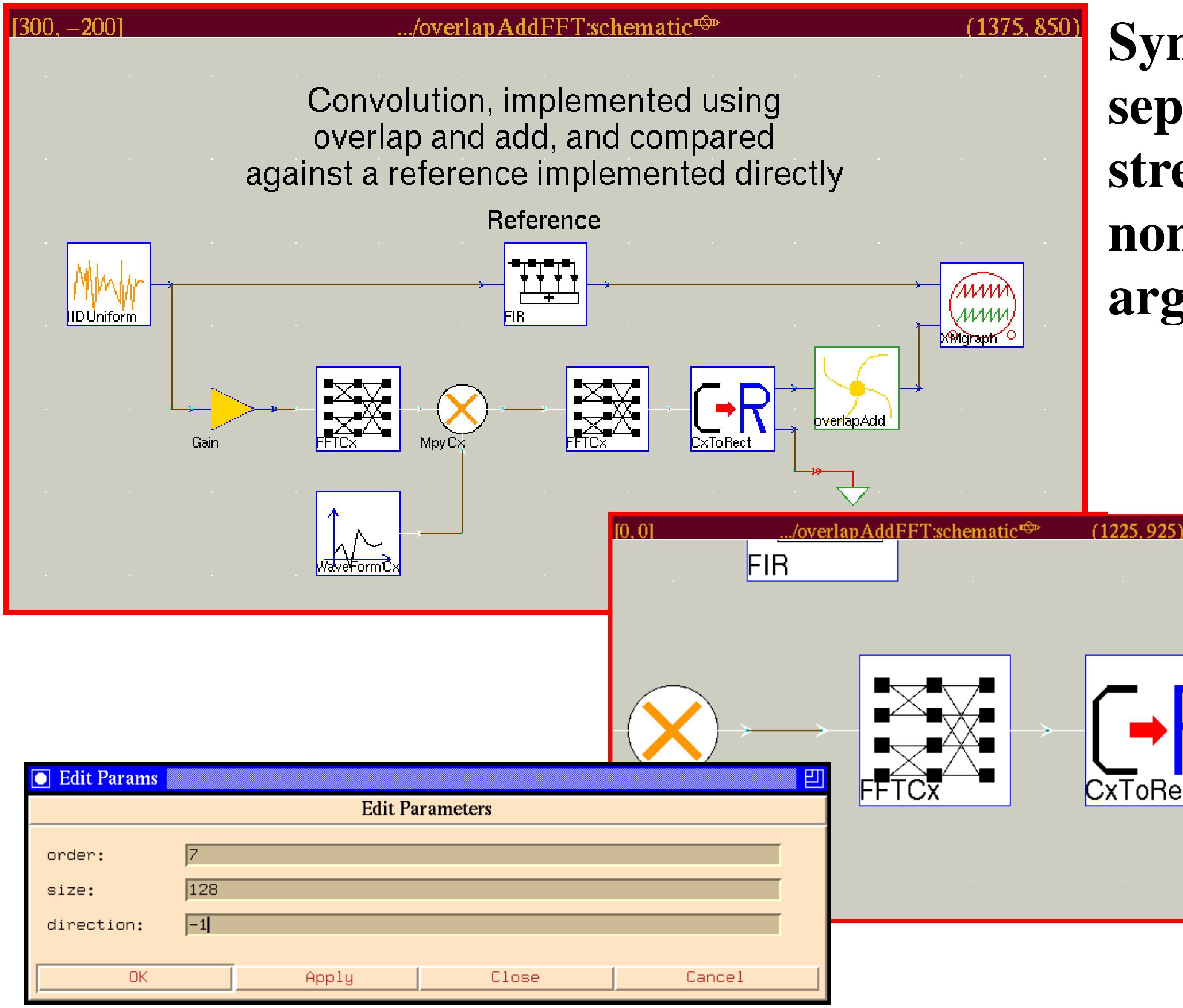
$$\text{scan}\ (f, \mathit{init}, (x{:}xs)) = f\ (x, \text{scan}(f, \mathit{init}, xs))$$

where $\perp$ means no arguments. So,

$$\text{scan}\ ((+), 0, \mathit{list})$$

adds all the elements of a list.

Key Idea in Visual Programming

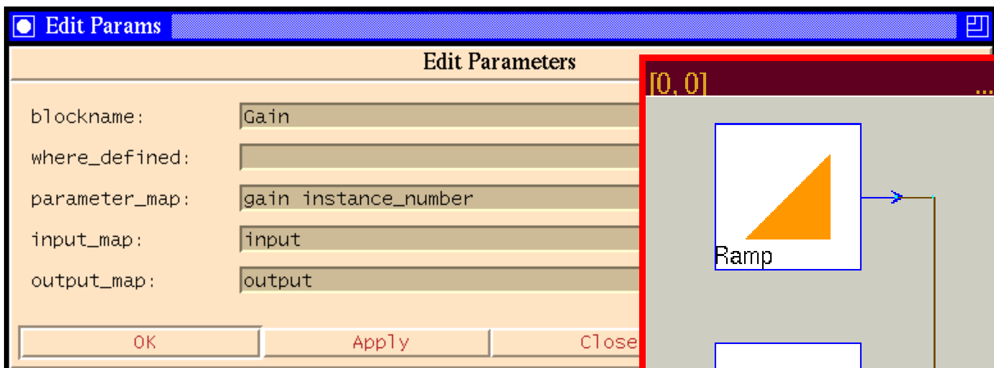


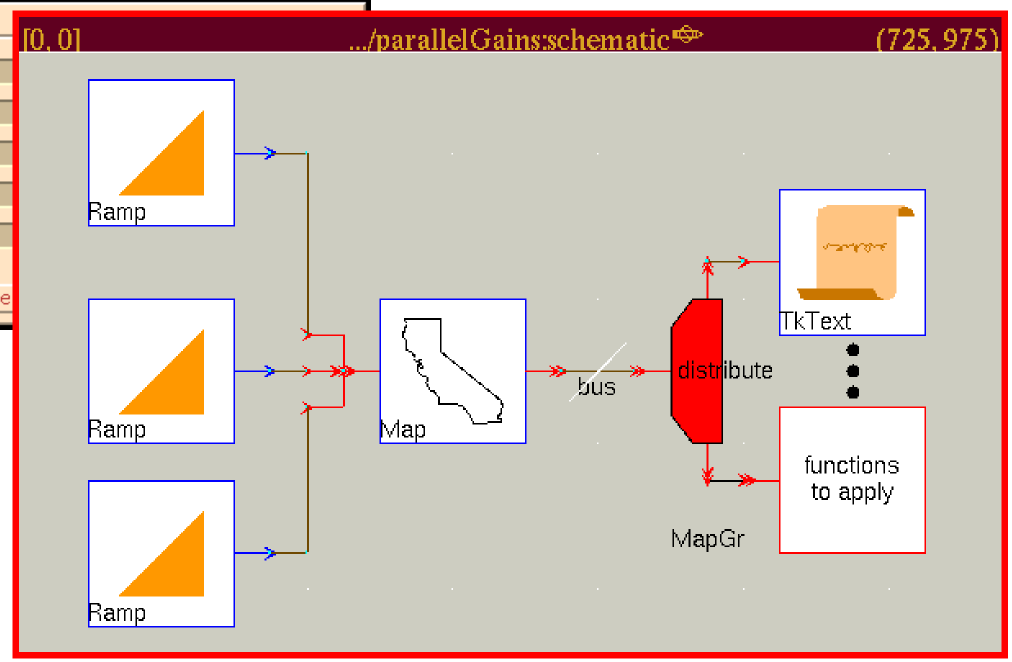
Syntactically separate stream and non-stream arguments.

Higher-Order Functions in Ptolemy

Examples implemented in Ptolemy:

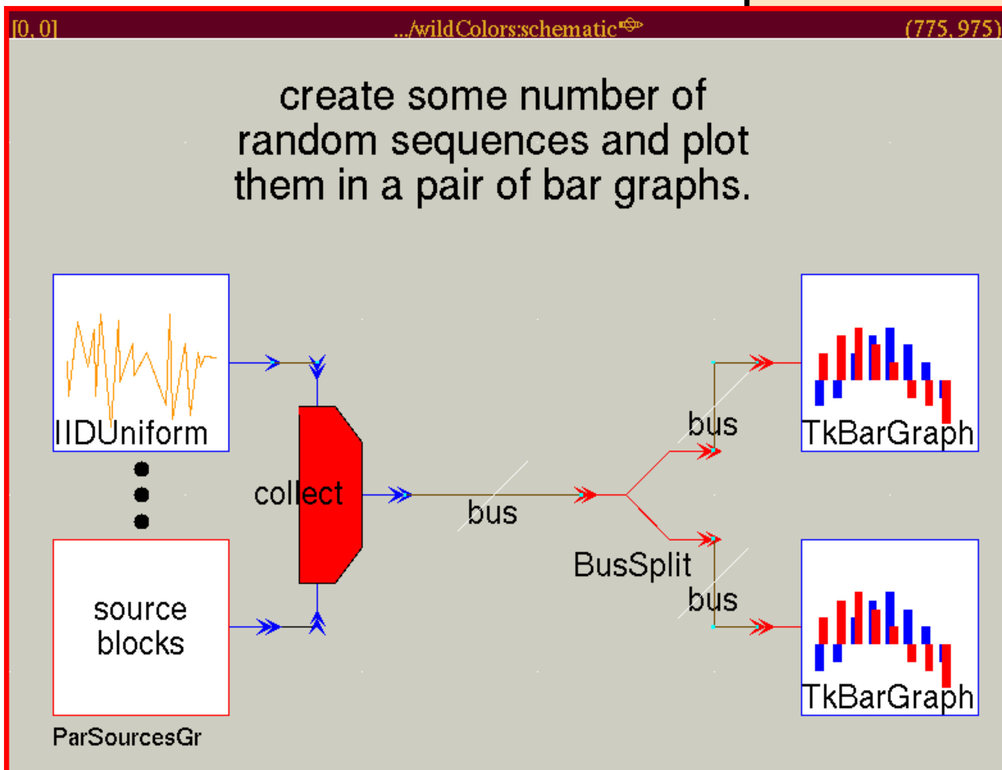
- **Map** (apply a specified function to all inputs)
- **MapGr** (graphical version of Map)
- **IfThenElse** (apply one of two specified functions)
- **Chain** (apply a specified function sequentially)

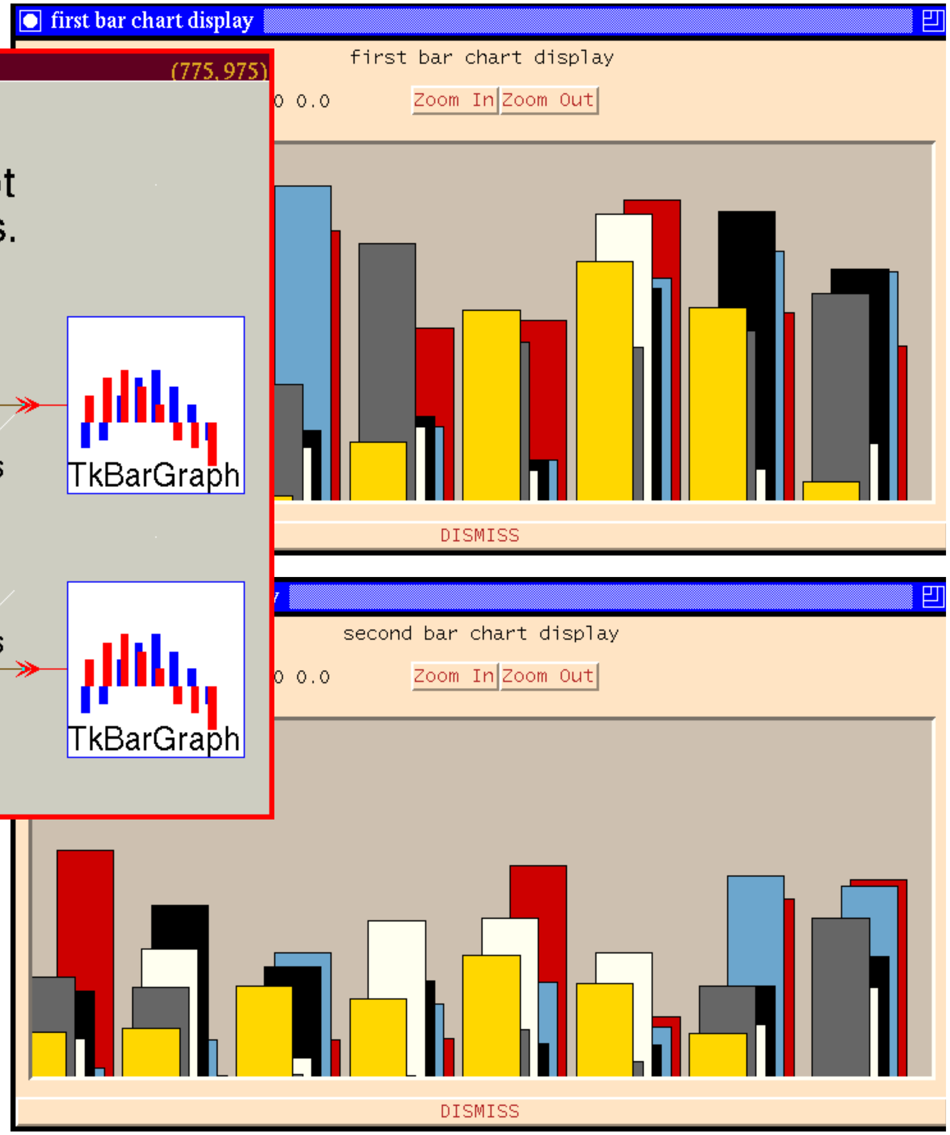




This example applies gains of 1, 2, and 3 to three successive ramp signals and displays the three results.

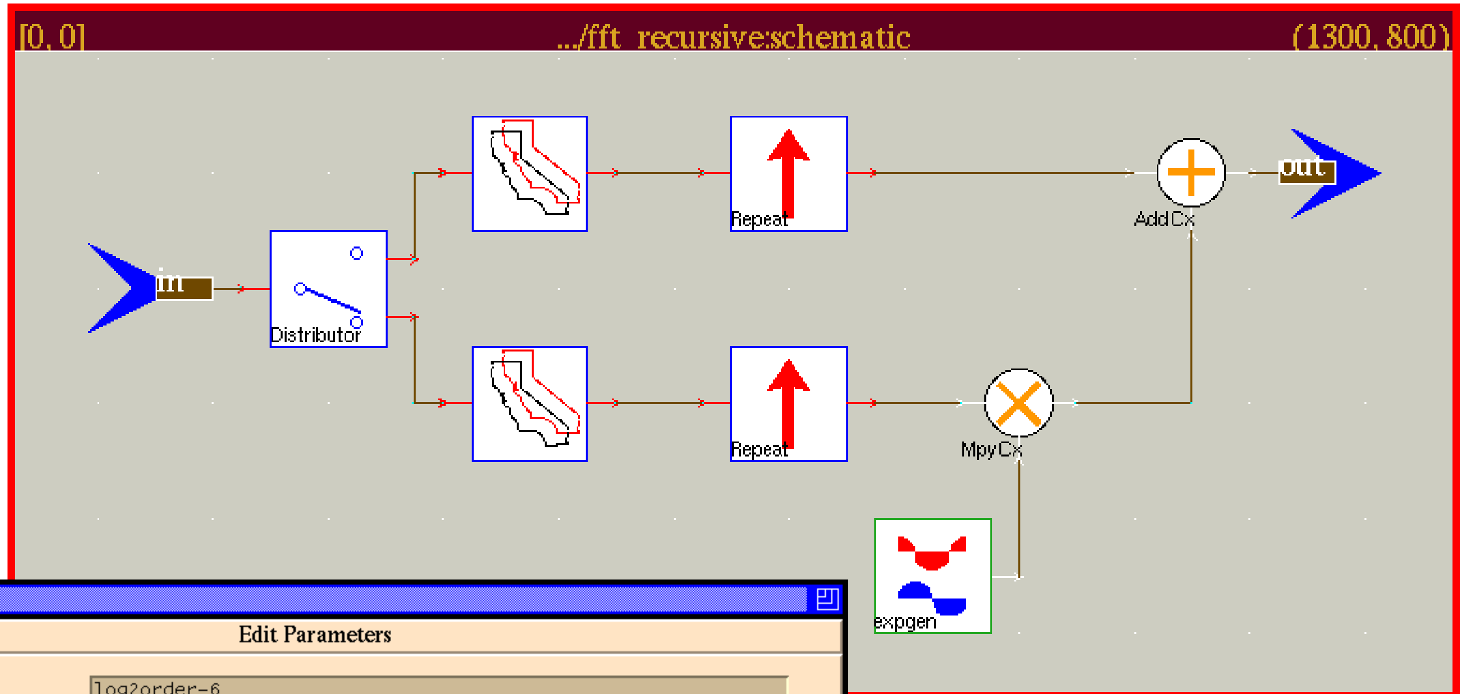
Generalization of Map to Signal Sources

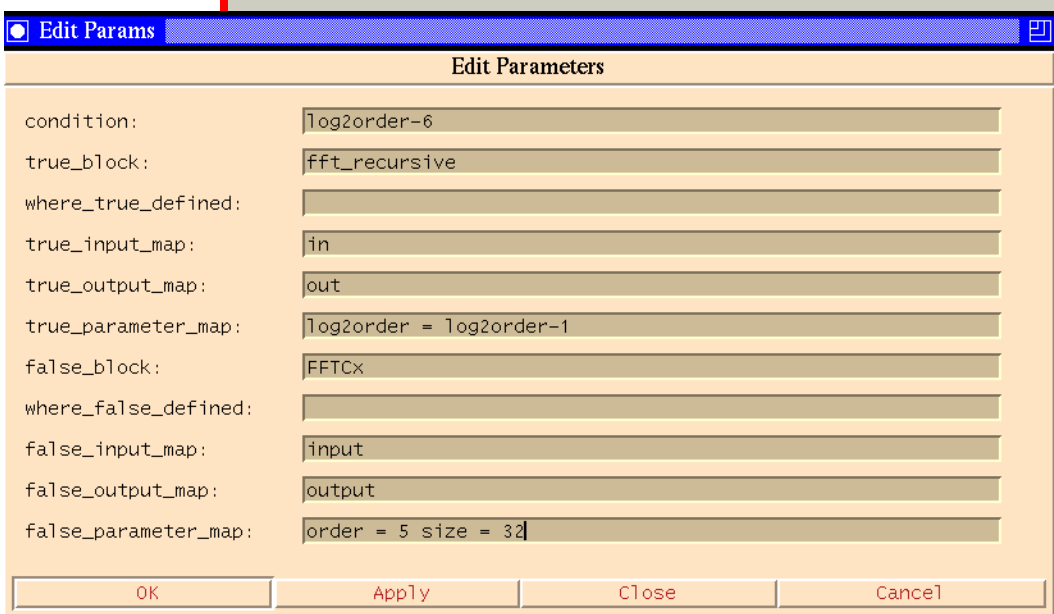




The ParSourcesGr (now called SrcGr) is a Map star with no inputs. The number of instances is determined by the number of outputs. The BusSplit is also an HOF star.

Using IfThenElse for Recursion





Edit Params

Edit Parameters

condition:	log2order-6
true_block:	fft_recursive
where_true_defined:	
true_input_map:	in
true_output_map:	out
true_parameter_map:	log2order = log2order-1
false_block:	FFTCx
where_false_defined:	
false_input_map:	input
false_output_map:	output
false_parameter_map:	order = 5 size = 32

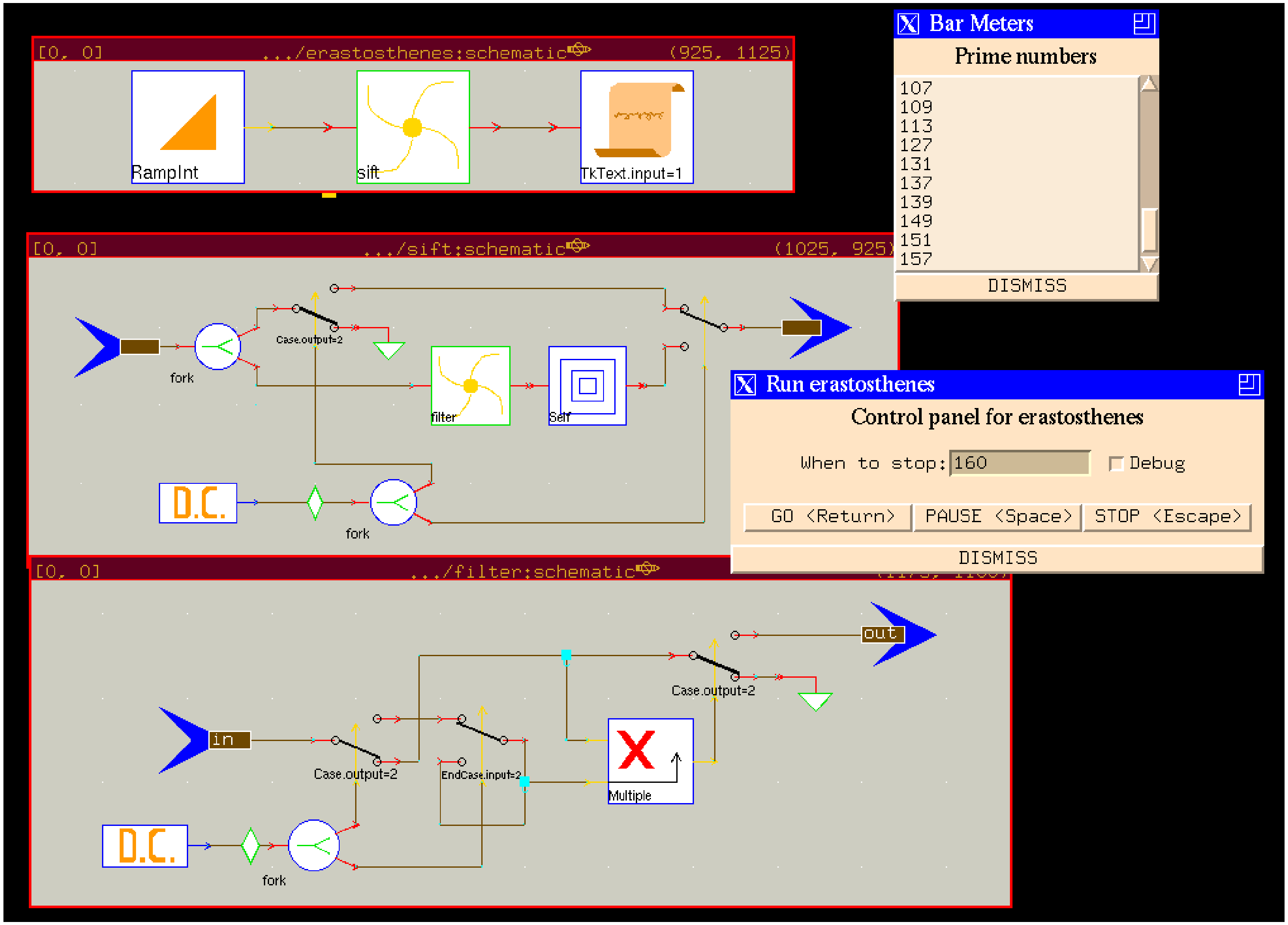
OK | Apply | Close | Cancel

Recursive FFT

granularity of the bottom-level operation is arbitrary

recursion can be unraveled at compile time, avoiding any run-time overhead

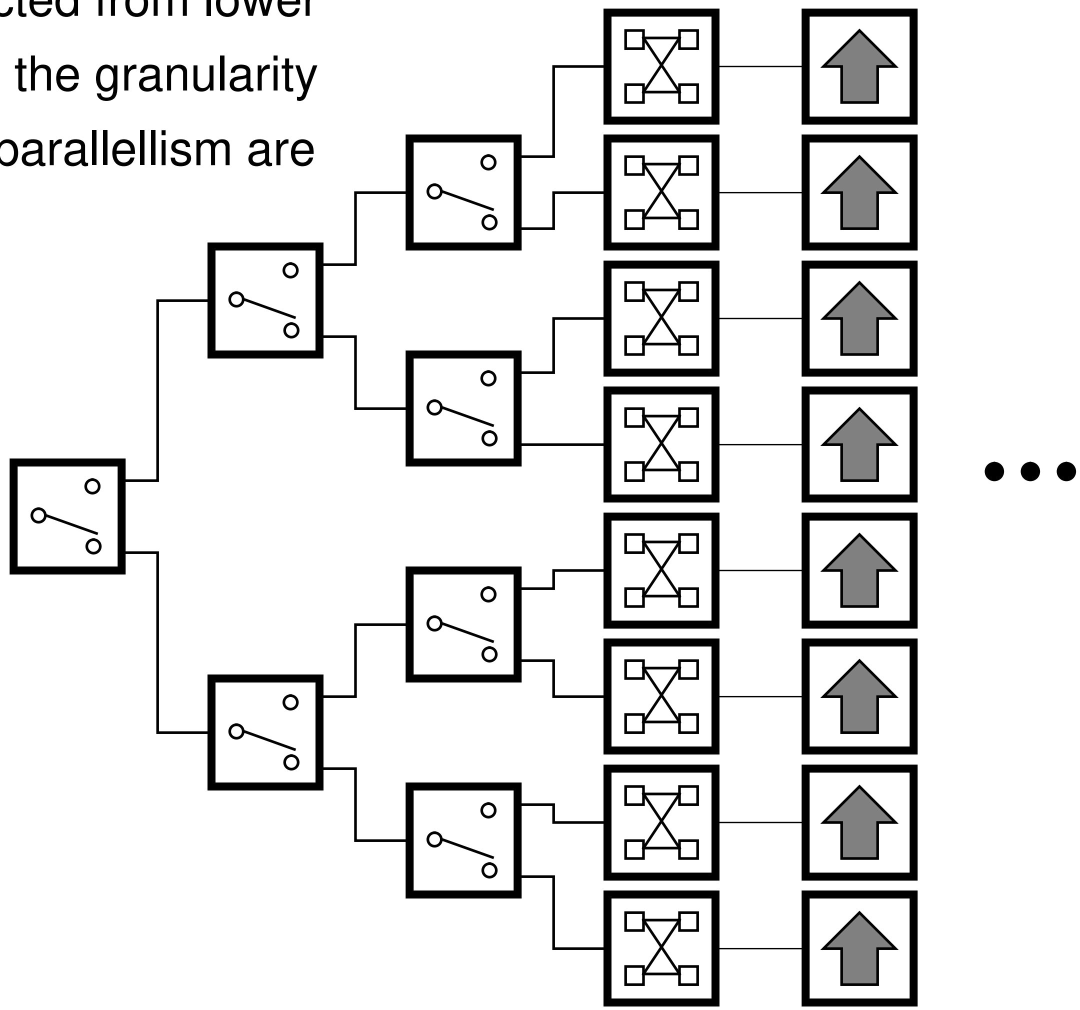
Using Map for Recursion in Dynamic Dataflow



The "sieve of Erastosthenes" is a highly irregular recursive algorithm for computing prime numbers. The DDF domain in Ptolemy can model algorithms of this type.

In SDF, recursion is statically unrolled

In our example, a high-order FFT is constructed from lower order FFTs. So the granularity and degree of parallellism are parameterized.



Conclusions

Advantages of higher-order functions:

- **Parameterizable parallelism**
- **Improved program modularity**
- **Scalable programming**
- **Recursion**
- **Zero run-time cost in most cases**
- **Expressiveness of a visual syntax**