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
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 parallelism are parameterized.
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.
Using IfThenElse for Recursion

Recursive FFT

granularity of the bottom-level operation is arbitrary
recursion can be unraveled at compile time, avoiding any run-time overhead
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.
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.
Key Idea in Visual Programming

Convolution, implemented using overlap and add, and compared against a reference implemented directly.

Syntactically separate stream and non-stream arguments.
Higher-Order Functions

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

\[ \text{map } f \]

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

\[
\begin{align*}
\text{scan } (f, \text{init}, \bot) &= \text{init} \\
\text{scan } (f, \text{init}, (x:xs)) &= f (x, \text{scan}(f, \text{init}, xs))
\end{align*}
\]

where \( \bot \) means no arguments. So,

\[ \text{scan } ((+), 0, \text{list}) \]

adds all the elements of a list.
Higher-Order Functions

Wan-Teh Chang
Edward A. Lee
Alan Kamas
Thomas M. Parks

UC Berkeley

Karim P. Khiar

Thomson SGS