

# Path Function Product Notation

by Sven Nilsen, 2017-2019

This notation is useful when doing asymmetric path semantics<sup>[1]</sup> in a way that can easily be reduced to symmetric path semantics by erasing indices.

A single lowered index annotates a cartesian product:

$$\begin{aligned}a_i &= (a_0, a_1, \dots, a_{n-1}) \\a_j &= (a_0, a_1, \dots, a_{m-1})\end{aligned}$$

`i` and `j` has paired cardinality with `n` and `m` respectively. When `n` and `m` are used as lowered indices, they can be thought of as an extra item at the end:

$$\begin{aligned}a_{in} &= (a_i, a_n) = (a_0, a_1, \dots, a_{n-1}, a_n) \\a_{jm} &= (a_j, a_m) = (a_0, a_1, \dots, a_{m-1}, a_m)\end{aligned}$$

A common technique in path semantics is to create partial function products, e.g.:

$$a_{in} = (x_i, f(x_i))$$

A lowered index paired with a raised index annotates function application per element:

$$f_i(x^i) = (f_0(x_0), f_1(x_1), \dots, f_{n-1}(x_{n-1}))$$

This makes it possible to apply a product of functions to a partial function product:

$$g_{in}(a^{in}) = g_{in}(x^i, f(x_i)) = (g_0(x_0), g_1(x_1), \dots, g_{n-1}(x_{n-1}), g_n(f(x_0, x_1, \dots, x_{n-1})))$$

For all partial function products of the same function:

$$(a_i = b_i) \Rightarrow (a_n = b_n)$$

A path function product  $g_{i \rightarrow n}$  splits the arguments from return value at `n`:

$$[g_{i \rightarrow n}] = [g_i \rightarrow g_n] = [g_0 \times g_1 \times \dots \times g_{n-1} \rightarrow g_n]$$

This means an asymmetric path can be turned into a symmetric path by erasing indices:

$$\begin{array}{ll}f[g_{i \rightarrow n}] & \text{asymmetric path} \\f[g] & \text{symmetric path}\end{array}$$

Equations often compare products:

$$\begin{aligned}g_i(x^i) &= g_i(y^i) \\(g_0(x_0), g_1(x_1), \dots, g_{n-1}(x_{n-1})) &= (g_0(y_0), g_1(y_1), \dots, g_{n-1}(y_{n-1}))\end{aligned}$$

## References:

- [1] “Algebraic Notation for Asymmetric Paths”  
Sven Nilsen, 2017  
[https://github.com/advancedresearch/path\\_semantics/blob/master/papers-wip/algebraic-notation-for-asymmetric-paths.pdf](https://github.com/advancedresearch/path_semantics/blob/master/papers-wip/algebraic-notation-for-asymmetric-paths.pdf)