

Semantic Design

The following is what I call a 'semantic design' for Nu's scripting system (as well as an unrelated replacement for micro-services called MetaFunctions). The concept of a semantic design is inspired by Conal Elliot's denotational design - <https://www.youtube.com/watch?v=bmKYiUOEo2A>.

To specify semantic designs generally, I've created a meta-language called SEDELA (for Semantic Design Language). First, we present the definition of SEDELA, then the semantic design for Nu's scripting system as well MetaFunctions in terms of SEDELA. Although I may aim to write a parser and type-checker for SEDELA, there will never be a compiler or interpreter. Thus, SEDELA will have no syntax for **if** expressions and the like. The only Meanings (SEDELA's nomenclature for functions) defined in the Prelude will be combinators such as `id`, `const`, `flip`, and etc. SEDELA's primitive types are all defined in terms of Axioms (types without formal definitions) with no available operations.

Sedela Language Definition

Axiom :=	Axiom[!] "Informal definition."	where ! denotes intended effectfulness
Meaning Type :=	A -> ... -> Z	where A ... Z are Type Expressions
Meaning Defn :=	f (a : A) ... (z : Z) : R = Expression Axiom	where f is the Meaning Identifier and a ... z are Parameter Identifiers and A ... Z, R are Type Expressions
Expression :=	Example: f a (g b)	where f and g are a Meaning Identifiers and a and b are Parameter Identifiers
Product :=	MyProduct<...> = A (A : A, ..., Z : Z) Axiom	where MyProduct<...> is the Product Identifier and A ... Z are Field Identifiers and A ... Z are Type Expressions
Sum :=	MySum<...> = A of (A Axiom) ... Z of (Z Axiom)	where MySum<...> is the Sum Identifier and A ... Z are Case Identifiers and A ... Z are Type Expressions
Type Identifier :=	Product Identifier Sum Identifier	
Type Expression :=	Meaning Type Type Identifier	
Type Parameters :=	Type Identifier < A, ..., Z; A<A, ..., Z>; ...; Z<...>>	where A ... Z are Type Expressions and A ... Z are Category Identifiers used for constraining A ... Z
Category :=	category MyCat<...> = f : A ... g : Z	where MyCat<...> is the Category Identifier and f ... g are Equivilence Identifiers and A ... Z are Types Expressions
Witness :=	witness A = f (a : A) ... (z : Z) : R = Expression ... g (a : A) ... (z : Z) : R = Expression	where A is a Category Identifier and f ... g are Equivilence Identifiers and a ... z are Parameter Identifiers and A ... Z, R are Type Expressions
Categorization :=	Rule: iff type A has a witness for category A, A is allowable for type parameter categorized as A	

Line Comment :=	Example: // comment text
fun a b ... z -> expr :=	\a (\b (... \z.expr))
a -> b :=	_ = (_ : a) : b
() :=	Explanation: The unit type / value.
f . g :=	Explanation: Function composition.

Sedela Language Prelude

```
Any = Axiom "The universal base type."
Bool = Axiom "A binary type."
Real = Axiom "A real number type."
Whole = Axiom "A whole number type."
String = Axiom "A textual type."
Maybe<a> = | Some of a | None
Either<a, b> = | Left of a | Right of b
List<a> = | Nil | Link of (a, List<a>)
Map<a, b> = | Leaf of (a, b) | Node of (Map<a, b>, Map<a, b>)
```

```
category Semigroup<a> =
  | append : a -> a -> a
```

```
category Monoid<m; Semigroup<m>> =
  | empty : m
```

```
category Functor<f> =
  | map<a, b> : (a -> b) -> f<a> -> f<b>
```

```
category Pointed<p> =
  | pure<a> : a -> p<a>
```

```
category FunctorPointed<f; Functor<f>; Pointed<f>>
```

```
category Applicative<p; FunctorPointed<p>> =
  | apply<a, b> : p<a -> b> -> p<a> -> p<b>
```

```
category Monad<m; Applicative<m>> =
  | bind<a, b> : m<a> -> (a -> m<b>) -> m<b>
```

```
category Alternative<l; Applicative<l>> =
  | empty<a> : l<a>
  | choice : l<a> -> l<a> -> l<a>
```

```
category Comonad<c; Functor<c>> =
  | extract<a> : c<a> -> a
  | duplicate<a, b> : c<a> -> c<c<a>>
  | extend<a, b> : (c<a> -> b) -> c<a> -> c<b>
```

```
category Foldable<f> =
  | fold<a, b> : (b -> a -> b) -> f<a> -> b
```

```
category Traversable<t; Functor<t>; Foldable<t>> =  
  | traverse<a, b, p; Applicative<f>> : (a -> p<b>) -> t<a> -> p<t<b>>
```

```
category Functor2<g; Functor<g>> =  
  | map2<a, b, c> : g<a> -> g<b> -> g<c>
```

```
category Producibile<p; Functor2<p>> =  
  | product<a, b> : p<a> -> p<b> -> p<(a, b)>
```

```
category Summable<s; Producibile<s>> =  
  | sum<a, b> : s<a> -> s<b> -> s<Either<a, b>>
```

```
category Foldable2<f; Foldable<f>> =  
  | fold2<a, b, c> : (c -> a -> b -> c) -> f<a> -> f<b> -> c
```

```
// TODO: define the Arrow categories.
```

```
id a = a  
const a _ = a  
flip f a b = f b a
```

Nu Script Semantic Design (script code is implementation-defined)

script (str : String) = Axiom "Denotes script code in str."

witness Monoid =

| append = script "+"
| empty = script "toEmpty -t-"

witness Monad =

| pure = script "[fun [a] [pure -t- a]]"
| map = script "map"
| apply = script "apply"
| bind = script "bind"

witness Foldable =

| fold = script "fold"

witness Functor2 =

| map2 = script "map2"

witness Summable =

| product = script "product"
| sum = script "sum"

Property = Axiom "A property of a simulant."

Relation = Axiom "Indexes a simulant or event relative to the local simulant."

Address = Axiom "Indexes a global simulant or event."

get<a> : Property -> Relation -> a = Axiom "Retrieve a property of a simulant indexed by Relation."

set<a> : Property -> Relation -> a -> a = Axiom! "Update a property of a simulant indexed by Relation, then returns its value."

Stream<a> = Axiom "A stream of simulant property or event values."

getAsStream<a> : Property -> Relation -> Stream<a> = script "getAsStream"

setAsStream<a> : Property -> Relation -> Stream<a> = script "setAsStream"

makeStream<a> : Address -> Stream<a> = script "makeStream"

mapStream<a, b> (a -> b) -> Stream<a> -> Stream = script "map"

foldStream<a, b> : (b -> a -> b) -> b -> Stream<a> -> b = script "fold"

map2Stream<a, b, c> (a -> b -> c) -> Stream<a> -> Stream -> Stream<c> = script "map2"

productStream<a, b> : Stream<a> -> Stream -> Stream<(a, b)> = script "product"

sumStream<a, b> : Stream<a> -> Stream -> Stream<Either<a, b>> = script "sum"

Semantic Design for MetaFunctions (a replacement for micro-services - unrelated to Nu)

```
Symbol =
  | Atom of String
  | Number of String
  | String of String
  | Quote of Symbol
  | Symbols of List<Symbol>
symbolToString (symbol : Symbol) : String = Axiom "Convert a symbol to string."
symbolFromString (str : String) : Symbol = Axiom "Convert a string to a symbol."

Vsync<a> =
  Axiom "The potentially asynchronous monad such as the one defined by Prime."
vsyncReturn<a> (a : a) : Vsync<a> =
  Axiom "Create a potentially asynchronous operation that returns the result 'a'."
vsyncMap<a, b> (f : a -> b) (vsync : Vsync<a>) : Vsync<b> =
  Axiom "Create a potentially asynchronous operation that runs 'f' over computation of 'a'."
vsyncApply<a, b> (f : Vsync<a> -> Vsync<b>) (vsync : Vsync<a>) : Vsync<b> =
  Axiom "Apply a potentially asynchronous operation to a potentially asynchronous value"
vsyncBind<a, b> (vsync : Vsync<a>) (f : a -> Vsync<b>) : Vsync<b> =
  Axiom "Create a potentially asynchronous operation."

witness Monad =
  | pure = vsyncReturn
  | map = vsyncMap
  | apply = vsyncApply
  | bind = vsyncBind

IPAddress = String
NetworkPort = Whole
Endpoint = (IPAddress, NetworkPort)
Intent = String // the intended meaning of a MetaFunction (indexes a MetaFunction from a Provider - see below)

Container = Intent -> Symbol -> Vsync<Symbol>
Provider = | Endpoint | Container
MetaFunction = Provider -> Intent -> Symbol -> Vsync<Symbol>

makeContainer (asynchronous : Bool) (repositoryUrl : String) (credentials : (String, String)) (envDeps : Map<String, Any>) :
Container = Axiom "Make a container configured with its Vsync as asynchronous or not, built from source pulled from the given
GIT url, and provided the given environmental dependencies."

attachDebugger (container : Container) = Axiom! "Attach debugger to code called inside the given container."
call (mfn : MetaFunction) provider intent args : Vsync<Symbol> = mfn provider intent args
```

Semantic Design for Unengine (a library for game programming without a monolithic game engine)

```
Time = Axiom "The current simulation time."
Input = Axiom "The current state of HID input."
Address = Axiom "A series of names denoting a simulant in the hierarchy."
Listener = Axiom "A generalized reference to a Listener<_>."
Simulant = Axiom "A generalized reference to a Simulant<_, _, _, _, _>."
RenderMsg = Axiom "A sum type representing the different render requests a simulant can send."
IOMsg<MyUpdateMsg> =
  | CreateSimulant of ... | DestroySimulant of ...
  | CreateListener of ... | DestroyListener of ...
  | CreatePhysicsBody of (Address, PhysicsBodyUpdateMsg -> MyUpdateMsg, ...)
  | DestroyPhysicsBody of ...
  | PlaySound of ...
  | ...

Listener<TheirUpdateMsg, MyUpdateMsg> =
  (Address : Address,
   Import : TheirUpdateMsg -> MyUpdateMsg)

Simulant<Config, State, UpdateMsg> =
  (Name : String,
   Persistent : Bool,
   Init : Config -> Time -> (State, List<UpdateMsg>),
   Sense : State -> Time -> Input -> (State, List<UpdateMsg>),
   Update : State -> Time -> UpdateMsg -> (State, List<UpdateMsg>, List<IOMsg<UpdateMsg>>),
   Draw : State -> Time -> List<RenderMsg>,
   Listeners : List<Listener>,
   Children : List<Simulant>)
```