Tridash Tutorials

REVISION HISTORY			
NUMBER	DATE	DESCRIPTION	NAME

Contents

This set of tutorials covers the basics of the Tridash programming language.

Prior programming experience is not strictly necessary however is helpful.

Tip
The full source code for these tutorials is available in the tutorials directory of the Tridash source: https://github.com/alex-gutev/tridash/tree/master/tutorials.

Hello Node

Nodes

A Tridash program is made up of a number of components called nodes, which are loosely analogous to variables in other languages. Each node holds a particular value, referred to as the node's state, at a given moment in time.

Nodes are created the first time they are referenced, by their identifiers. Node identifiers can consist of any sequence of Unicode characters excluding whitespace, parenthesis `(`, `)`, braces `{`, `}`, double quotes `"` and the following special characters: `;`, `,`, `.`, `#`. A node identifier must consist of at least one non-digit character otherwise it is interpreted as a number.

The following are examples of valid node identifiers:

- `name`
- `full-name`
- `node1`
- `1node`

Tip
There are few restrictions on the characters allowed in node identifiers, meaning node identifiers may even contain symbols such as `-`, `+`, `=`, `>`, `?`, etc.

A node can be bound to another node in which case its value is automatically updated when the value of the node, to which it is bound, changes.

The `->` operator establishes a binding between node on the left hand side, referred to as the *source*, and the node on the right hand side, referred to as the *target*.

Example

```
a -> b
```

Important
The spaces between the node identifiers and the bind `->` operator are mandatory since `a->b` is a valid node identifier and is thus interpreted as a single node.

In this example a binding is established between node `a` and node `b`. The result is that when the value of `a` changes, the value of `b` is automatically updated to match the value of `a`. This kind of binding is known as a simple binding since a node is simply set to the value of another node. Node `a` is referred to as a *dependency* node of `b`, since `b`'s value depends on the value of `a`, and `b` is referred to as an *observer* node of `a` since it actively observes its value.

First Application

We'll use bindings to develop a simple application which asks for the user's name and displays a greeting.

This tutorial targets the JavaScript backend and makes use of HTML for the user interface.

Note

Some knowledge of the basics of HTML, i.e. what tags, elements and attributes are, is necessary to complete this tutorial.

We'll start off by creating an HTML file, called `hello-ui.html`, with the following contents:

hello-ui.html

```
<?
 self.input-name.value -> name
 name -> self.span-name.textContent
?>

<!doctype html>
<html>
    <head>
        <title>Hello Node</title>
    </head>
    <body>
        <h1>Tutorial 1: Hello Node</h1>
        <label>Enter your name: <input id="input-name"/></label>
        <p>Hello <span id="span-name"></span></p>
    </body>
</html>
```

Most of the file is HTML boilerplate, the interesting part is within the `<?...?>` tag. The content of this tag is interpreted as Tridash code. Tridash code tags can be placed almost anywhere in the file, we've just chosen to place it at the top.

The Tridash code consists of two explicit binding declarations. Declarations are separated by a line break or a semicolon `;`.

Tridash Code

```
self.input-name.value -> name
name -> self.span-name.textContent
```

The declaration in the first line binds the `self.input-name.value` node to the `name` node.

The node `self.input-name` is a special node that references the `input` element, with id `input-name`, in the HTML file. HTML elements can be referenced from within Tridash code, in the same HTML file, using the expression `self.<id>` where `<id>` is substituted with the id of the element.

Tip

The `.` operator is a special operator for referencing subnodes of nodes, these will be explained in detail later. The subnode identifier is the identifier which appears to the right of the operator. When a subnode of a node, that references an HTML element, is referenced, the HTML attribute, of the element, with the same name as the subnode identifier is referenced. Referencing attributes of HTML elements, from Tridash, allows the values of attributes to be bound to Tridash nodes.

The node `self.input-name.value`, which references the `value` attribute of the HTML element with ID `input-name`, is bound to the node `name`. Thus whenever the value of `input-name.value` changes, the value of `name` is set to it. In other words, whenever text is entered in the input element, the value of `name` is automatically set to the text entered.

In the second declaration, the `name` node is bound to the `self.span-name.textContent` node. `self.span-name` references the HTML `span` element with ID `span-name`, with the node `self.span-name.textContent` referencing the `textContent` attribute, i.e. the content, of the element. The result of this binding is that whenever the value of the `name` node changes, its value is displayed in the `span` element. As mentioned earlier, the value of the `name` node is automatically set to the text entered in the `input` element, thus the value entered in the `input` element is displayed in the `span` element.

The application we've just written, simply prompts the user for his/her name and displays "Hello" followed by the user's name directly below the prompt. Let's try it out to see if it works.

Building

Run the following command to build the application:

```
tridashc hello-ui.html : node-name=ui -o hello.html -p type=html -p main-ui=ui
```

That looks complicated, let's simplify it a bit.

The `tridashc` executable compiles one or more Tridash source files, generating an output file. The source files, in this case `hello.html`, are listed after `tridashc`. The name of the output file is given by the `-o` or `--output-file` option, in this case `hello.html`.

The snippet `:node-name=ui` sets the `node-name` option, for processing the source file `hello-ui.html`, to `ui`. This creates a node `ui` with which the contents of the HTML file can be referenced.

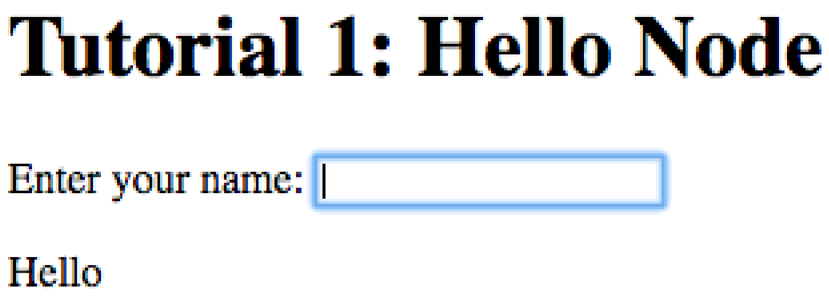
> **Tip**
> The `self` node, when occurring within an HTML file is simply an alias for the node name, given by the `node-name` option, which references the contents of the HTML file.

The `-p option=value` command-line options sets various options related to the compilation output. The first option `type` is set to `html` which indicates that the output should be an HTML file with the generated JavaScript code embedded in it. The `main-ui` option is set to `ui`, which is the name of the node referencing the contents of the `hello-ui.html` file. It is the contents of this file that are used to generate the output HTML file.

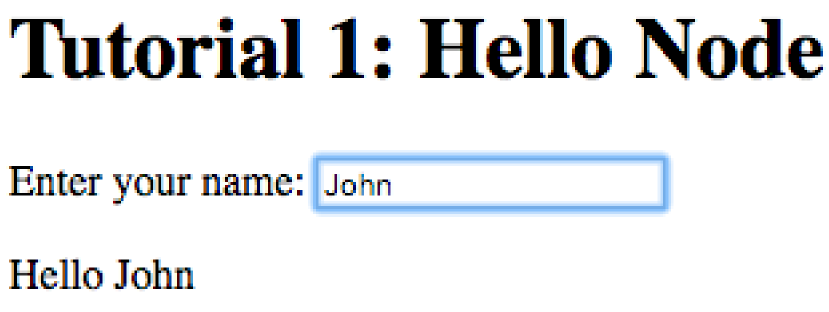
If all went well a `hello.html` file should have been created in the same directory, after running the command.

Running The Application

Open the `hello.html` file in a web-browser with JavaScript enabled. You should see something similar to the following:

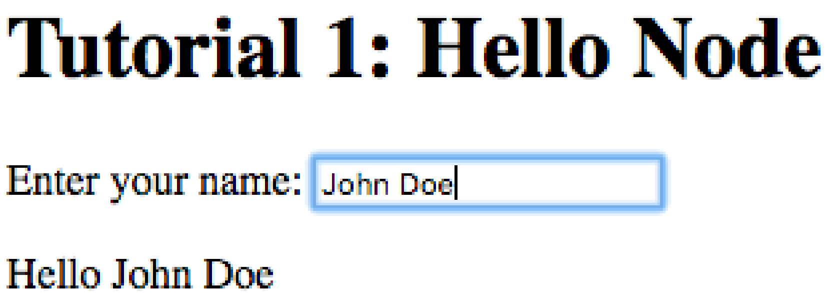


Try entering some text in the text field, and press enter afterwards:



Notice that the text entered appears next to the “Hello” message underneath the text field. This is due to the binding of the text field to the `name` node and the binding of the `name` node to the contents of the `span` element placed adjacent to the “Hello” text.

Now try changing the text entered in the text field:



The text changes to match the contents of the text field. This demonstrates the automatic updating of a node’s state when the state of its dependency nodes changes.

When the state (the value) of the text field changes:

1. The state of the `name` node is updated to the text entered in the field.
2. The content of `span` element is updated to match the state of the `name` node.

Inline Node Declarations

The previous application can be implemented much more succinctly using implicit bindings and inline node declarations.

hello-ui.html

```
<!doctype html>
<html>
    <head>
        <title>Hello Node</title>
    </head>
    <body>
        <h1>Tutorial 1: Hello Node</h1>
        <label>Enter your name: <input value="<?@ name ?>"/></label>
        <p>Hello <?@ name @></p>
    </body>
</html>
```

Implicit bindings between an HTML node and a Tridash node can be established using the `<?@declaration ?>` tag. This is similar to the Tridash code tag, seen earlier, however an implicit binding is established between the nodes appearing in the tag and the HTML node in which the tag appears.

If the tag is placed within an attribute of an element, an implicit two-way binding is established between the element's attribute and the node, appearing in the tag. If the tag appears outside an attribute, an HTML element is created in its place, and a binding is established between the node appearing in the tag, and the content of the element (referenced as `textContent` from Tridash).

With inline declarations it is not necessary to give the HTML elements unique ID's unless they will be referenced from within Tridash code. In this example they have been omitted.

Two-Way Bindings

The bindings we've seen so far are one-way bindings, as data only flows in one direction, from the dependency node to the observer node.

Example: One-Way Binding

```
a -> b
```

This is a one-way binding since the value of `b` is updated to the value of `a` when it changes, however, `a` is not updated when the value of `b` changes.

If a binding in the reverse direction is also established:

```
b -> a
```

the binding becomes a two-way binding since the value of each node is updated when the value of the other node changes.

Example Application

The following simple application demonstrates two-way bindings:

ui.html

```
<?
 a -> b
 b -> a
?>

<!doctype html>
<html>
  <head>
    <title>Two-Way Bindings</title>
  </head>
  <body>
    <h1>Two-Way Bindings</h1>
    <div><label>A: <input value="<?@ a ?>"/></label></div>
    <div><label>B: <input value="<?@ b ?>"/></label></div>
  </body>
</html>
```

The applications consists of two text input fields with the first field bound to node `a` and the second field bound to `b`, using inline node declarations.

In the Tridash code tag, a two-way binding between `a` and `b` is established since a binding is declared in both directions:

- `a -> b`
- `b -> a`

Build the application using the following command, which is identical to the previous build command with only the source and output file names changed.

```
tridashc ui.html : node-name=ui -o app.html -p type=html -p main-ui=ui
```

Open the resulting `app.html` file in a web-browser, and enter a value in the first text field:

Notice that the content of the second text field is automatically updated to match the content of the first field.

Now change the value in the second field:

The value of the first field is updated to the value entered in the second field.

Functional Bindings

The bindings in the previous tutorial were pretty boring and limited. Whatever was entered in the text field was simply displayed below it, verbatim. In-fact, this functionality is already offered by many web frameworks and GUI toolkits. The real power of the Tridash language comes from the ability to specify arbitrary functions in bindings which are dependent on the values of more than a single node. Moreover these bindings can be established in Tridash itself without having to implement "transformer" or "converter" interfaces/subclasses in a lower-level language.

A functor node is a node which is bound to a function of the values of one or more nodes. It consists of an expression comprising an operator applied to one or more arguments.

Functor Node Syntax

```
operator(argument1, argument2, ...)
```

A binding is established between the argument nodes and the functor node. Whenever the value of one of the argument nodes changes, the expression is reevaluated and the value of the functor node is updated.

Example: Functor of one argument

```
to-int(a)
```

The functor node is `to-int(a)` consisting of the function `to-int`, which converts its argument to an integer, applied to the value of node `a`. When the value of `a` changes, the value of `to-int(a)` is updated to `a`'s value converted to an integer.

Example: Functor of two arguments

```
a + b
```

This is a functor node of the function + which computes, you guessed it, the sum of its arguments, in this case `a` and `b`. Whenever the value of either `a` or `b` changes, the value of `a + b` is updated to the sum of `a` and `b`.

> **Note**
> The + operator is registered as an infix operator, meaning it can be placed between its two arguments (infix notation), instead of being placed before its arguments (prefix notation). `a + b` is transformed to prefix notation `+(a, b)`, when parsed. Both notations are equivalent and either notation can be written in source code.

> **Important**
> The spaces between an infix operator and its arguments are mandatory since `a+b` is a valid node identifier and is thus interpreted as a single node with identifier `a+b`, rather than a functor node of the + operator.

Functor nodes can be bound to other nodes using the same `->` operator.

Example: Binding functors to other nodes

```
a + b -> sum
```

In this example node `sum` is bound to `a + b` which is bound to the sum of `a` and `b`.

Example Application: Adding Numbers

We'll build an application which computes the sum of two numbers, entered by the user, and displays the result.

Let's focus on building the interface for now. Begin with the following `ui.html` file:

ui.html

```
<!doctype html>
<html>
    <head>
        <title>Adding Numbers</title>
    </head>
    <body>
      <h1>Adding Numbers</h1>
      <div><label>A: <input value="<?@ a ?>"/></label></div>
      <div><label>B: <input value="<?@ b ?>"/></label></div>
      <hr/>
      <div><strong>A + B = <?@ sum ?></strong></div>
    </body>
</html>
```

An interface consisting of two text input fields is created. The first field is bound to node `a` and the second to node `b`. Underneath the fields the node `sum` is bound to an unnamed HTML element located next to "A + B =".

Nodes `a` and `b` are bound to the values of the two numbers. Node `sum` is to be bound to the sum of `a` and `b`.

Before we begin writing the binding declarations we need to import the nodes from the `core` module, *you'll learn more about modules in a later tutorial*, which we'll be making use of in this application. The following imports all nodes from the `core` module:

Import all nodes from module core

```
/import(core)
```

Nodes `a` and `b` are bound to the contents of the text fields, however the contents of the text fields are strings. We need to convert `a` and `b` to integers in order to compute the sum. This is achieved using the `to-int` operator.

The sum of the integer values of `a` and `b` is computed using the `+` operator applied on the arguments `to-int(a)` and `to-int(b)`.

Computing Sum of a and b

```
to-int(a) + to-int(b)
```

Finally, we need to bind the sum to the node `sum` in order for it to be displayed below the fields.

```
to-int(a) + to-int(b) -> sum
```

Adding the declarations, we've written so far, to a Tridash code tag (somewhere in the file such as at the beginning), completes the application.

Tridash Code Tag

```
<?
 /import(core)

 to-int(a) + to-int(b) -> sum
?>
```

Build Configuration File

To simplify the build command, the build options are specified in a build configuration file.

The build configuration file contains the list of sources, along with the source-specific options, and the output options in YAML syntax *(see https://yaml.org for details)*.

Create the following `build.yml` file:

build.yml

```
sources:
  - path: ui.html
    node-name: ui

output:
  path: app.html
  type: html
  main-ui: ui
```

The outer structure of the file is a dictionary with two entries `sources` and `output`.

The `sources` entry contains the list of source files either as a path or as a dictionary with the path in the `path` entry and the processing options in the remaining entries. In this application there is one source file `ui.html` with one source processing option `node-name` set to `ui`.

The `output` entry is a dictionary containing the path to the output file in the path entry, in this case `app.html`, and the output options in the remaining entries, in this case `type =html` and `main-ui =ui` which are the same options as in the previous tutorials.

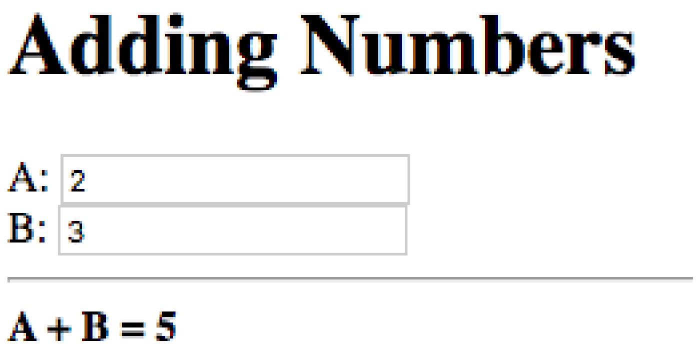
To build from a build configuration file run the following command:

```
tridashc -b build.yml
```

The `-b` option specifies the path to the build configuration file containing the build options. All other command line options are ignored when this option is specified.

Running the Application

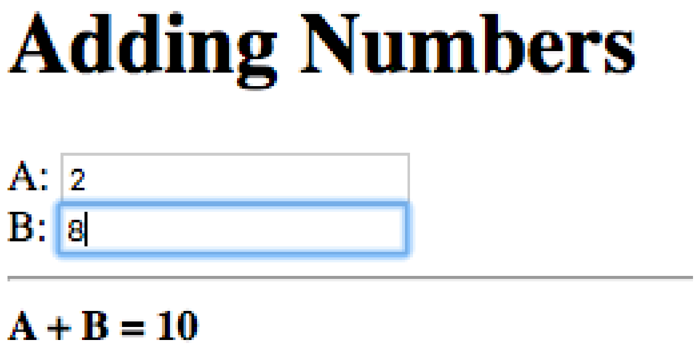
Open the `app.html` file in a web browser, and enter some numbers in the text fields:



Notice that the sum of the numbers is automatically computed and displayed below the fields.

> **Note**
> The sum will only be displayed once you have entered a valid number in each field.

Now try changing the numbers (*remember to press enter afterwards*):



Notice that the sum is automatically recomputed and the new sum is displayed.

Binding to Functor Nodes

The `to-int` operator is special in that a two-way binding is established between its argument and the functor node. Thus the declaration `to-int(a)` also establishes the binding `to-int(a) -> a`. The binding in the reverse direction, from functor to argument, has the same function as the binding from the argument to the functor. Thus in `to-int(a) -> a`, `a` is bound to the value of `to-int(a)` converted to an integer.

This allows a binding to be established with a `to-int` functor node as the observer.

Example: Binding with to-int as observer

```
x -> to-int(a)
```

In this example, `to-int(a)` is bound to `x`. Whenever the value of `x` changes, the value of `to-int(a)` is set to it, and the value of `a` is set to the value of `to-int(a)` converted to an integer.

With this functionality, the application in this tutorial can be implemented more succinctly by moving the integer conversion from the Tridash code tag to the inline node declarations.

Replace the declaration:

```
to-int(a) + to-int(b) -> sum
```

with:

```
a + b -> sum
```

Replace `<?@a ?>` and `<?@b ?>` with `<?@to-int(a) ?>` and `<?@to-int(b) ?>` respectively.

The benefit of this is that the value conversion logic is moved closer to the point where the values are obtained, rather than being littered throughout the core application logic. Nodes `a` and `b` can now be used directly, without having to be converted first, since it is known that they contain integer values.

To simplify the application further, the `sum` node can be omitted entirely and `<?@sum ?>` can be replaced with `<?@a + b ?>`.

Improved Application

```
<?
 /import(core)
?>
<!doctype html>
<html>
    <head>
        <title>Adding Numbers</title>
    </head>
    <body>
      <h1>Adding Numbers</h1>
      <div><label>A: <input value="<?@ to-int(a) ?>"/></label></div>
      <div><label>B: <input value="<?@ to-int(b) ?>"/></label></div>
      <hr/>
      <div><strong>A + B = <?@ a + b ?></strong></div>
    </body>
</html>
```

Important
The `/import` declaration in the Tridash code tag has to be retained as it is responsible for importing the nodes `to-int` and `+` from the `core` module.

Conditional Bindings

This tutorial introduces functionality for conditionally selecting the value of a node.

Case Operator

The special `case` operator selects the value of the first node for which the value of the corresponding condition node is true. The `case` operator is special in that it has a special syntax to make it more readable.

Tip

The `case` operator is actually a macro-node, implemented in Tridash, which expands to a series of nested `if` functor expressions. You can views its source in the `modules/core/macros.trd` file of your Tridash installation.

Syntax

```
case(
  condition-1 : value-1,
  condition-2 : value-2,
  ....
  default-value
)
```

Each argument is of the form `condition :value` where `condition` is the condition node and `value` is the corresponding value node. The last argument may also be of the form `value`, that is there is no condition node, in which case it becomes the *default* or *else* value.

The `case` functor node evaluates to the value of the value node corresponding to the first condition node which has a *true* value (equal to the value of the builtin node `True`), or the value of the default node, if any, when all condition nodes have a *false* (equal to the value of the builtin node `False`) value.

Example

```
case(
  a > b : a - b
  b > a : b - a
  0
)
```

If the node `a > b` evaluates to true, the `case` node evaluates to the value of `a -b`, otherwise if `b > a` evaluates to true, the `case` node evaluates to the value of `b -a`. If neither `a > b` nor `b > a` evaluate to true, the `case` node evaluates to `0`.

If the default value node is omitted and no condition node evaluates to true, the `case` node evaluates to a failure value (*you will learn about failure values in a later tutorial which introduces error handling*).

Example 1: Maximum of Two Numbers

Let's write a simple `case` expression which returns the maximum of two numbers, `a` and `b`, and returns the string "neither" when neither number is greater than the other.

The `case` expression should evaluate to:

1. `a` if `a > b`
2. `b` if `b > a`
3. The string "neither" otherwise

These conditions are implemented by the following `case` expression:

```
case(
    a > b : a,
    b > a : b,
    "neither"    ❶
)
```

1 This is the literal string “neither”.

Tip
String constants are written in double quotes `"..."`.

Notice that the last argument does not have an associated condition. The `case` node evaluates to this argument if none of the conditions, of the previous arguments, evaluate to true.

We can incorporate this in a simple application, which displays the maximum of two numbers entered by the user, using the following HTML interface:

ui.html

```
<?
 /import(core)

 maximum <-
     case (
         a > b : a,
         b > a : b,
         "neither"
     )
?>
<!doctype html>
<html>
    <head>
        <title>Maximum</title>
    </head>
    <body>
      <h1>Maximum</h1>
      <div><label>A: <input value="<?@ to-int(a) ?>"/></label></div>
      <div><label>B: <input value="<?@ to-int(b) ?>"/></label></div>
      <hr/>
      <div><strong>The maximum of <?@ a ?> and <?@ b ?> is <?@ maximum ?>.</strong></div>
    </body>
</html>
```

Tip
The `<-` operator is the same as the `->` operator however with the arguments reversed, that is `b <-a` is equivalent to `a -> b`.

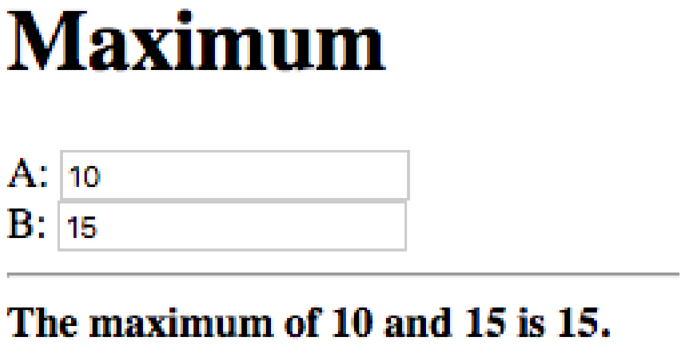
The interface consists of two text fields, the contents of which are bound to nodes `a` and `b`. The `to-int` operator is used to convert the string values to integers as in the previous tutorial.

The node `maximum` is bound to the value of the `case` functor, and its value is displayed in an unnamed HTML element below the input fields.

Note
The values of `a` and `b` are also displayed below the input fields. This is to demonstrate that there is no limit to how many nodes can be bound to a particular node.

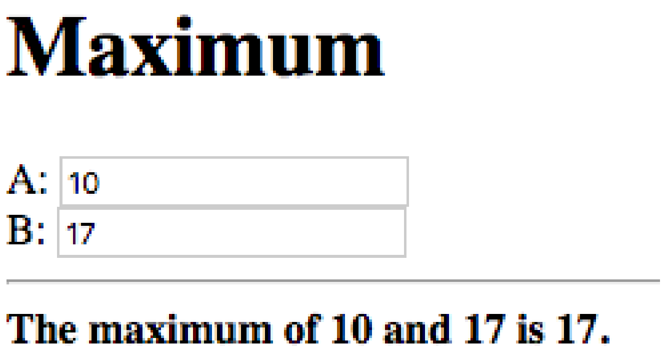
Build and run the application, using the same build configuration file and command from the previous tutorials.

Enter some numbers in the text fields:



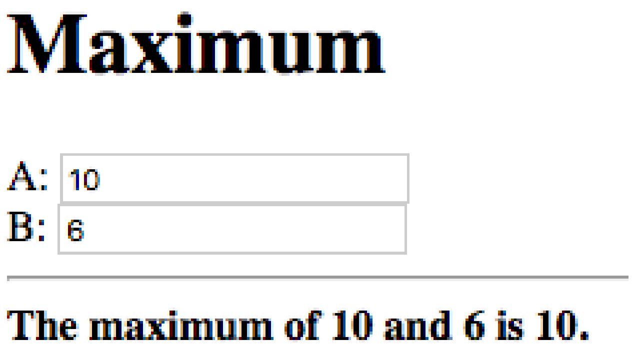
Notice that the maximum, 15 in this case, is displayed below the text fields. Also notice that the values entered in the text fields are also displayed as part of the message.

Now change the number, which is the maximum, to a different value which is still greater than the other number:



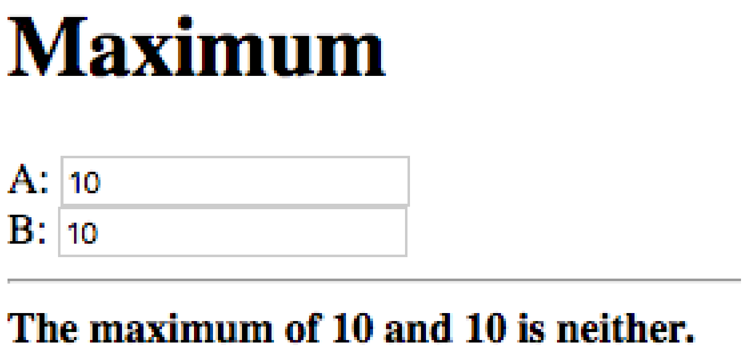
The new maximum is displayed. This demonstrates that if the values of the value nodes, of the `case` expression change, the value of the `case` expression is updated.

Change the maximum number such that it is smaller than the other number:



This shows that the value of the `case` expression is also updated if the values of the condition nodes change.

Now finally change the numbers such that they are both equal:



The displayed maximum is “neither” which is the default value of the case expression.

Example 2: Sum Limit

Let’s extend the application developed during the previous tutorial by adding the functionality for specifying a limit to the sum of the two numbers. The application should inform the user of whether the limit was exceeded.

Start with the following slightly modified code from the previous tutorial.

```
<?
 /import(core)

 a + b -> sum
?>
<!doctype html>
<html>
    <head>
        <title>Sum Limit</title>
    </head>
    <body>
      <h1>Sum Limit</h1>
      <div><label>Limit: <input value="<?@ to-int(limit) ?>"/></label></div>
      <hr/>
      <div><label>A: <input value="<?@ to-int(a) ?>"/></label></div>
      <div><label>B: <input value="<?@ to-int(b) ?>"/></label></div>
      <hr/>
      <div><strong>A + B = <?@ sum ?></strong></div>
    </body>
</html>
```

A new text input field for the limit has been added, with its value bound to the node `limit`.

Note
The sum `a + b` is bound to the node `sum` in order to facilitate the implementation of the new features.

The message “Within limit.” should be displayed if the sum is less than the limit (`sum < limit`), and “Limit Exceeded!” otherwise. This can be implemented using the following `case` expression, which is bound directly to an unnamed element.

Add the following below the element where the sum is displayed.

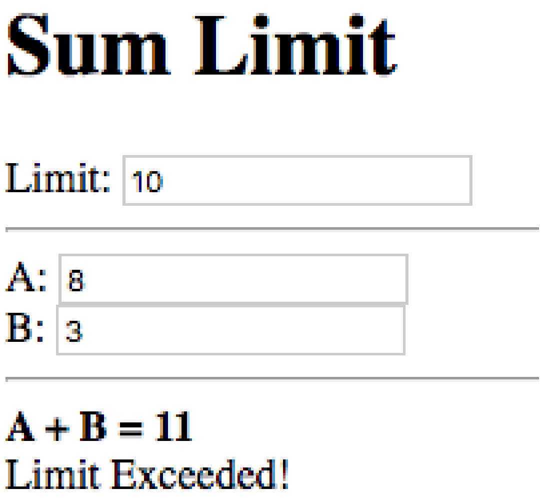
```
<div>
  <?@
    case(
        sum < limit : "Within Limit.",
```

```
        "Limit Exceeded!"
    )
  ?>
</div>
```

Note

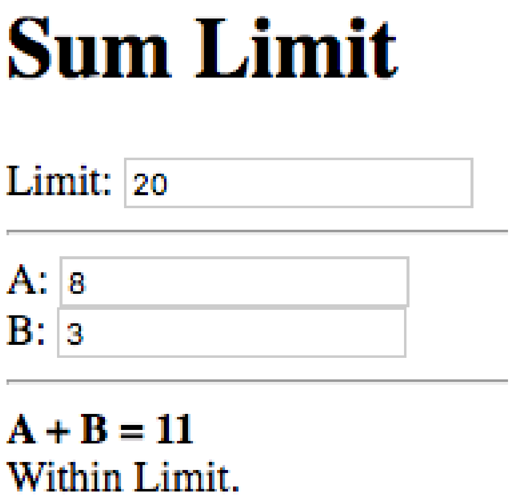
There is no difference in efficiency between using the `sum` node or `a + b` directly. The value of a node is only computed once, whenever one of its arguments changes, even if it is referenced in more than one location. Moreover the value of a node is not computed if it is not used anywhere.

Build and run the application, and enter some initial values for the limit, `a` and `b`.



“Limit Exceeded!” is displayed since the sum of 11 did indeed exceed the limit of 10, with the numbers in the snapshot above.

Now try increasing the limit:



The message changes to “Within Limit.”.

Improvements

Whilst the application we've implemented so far demonstrates the power of functional bindings, it is rather lacking in that whether the limit has been exceeded or not is only indicated by text. The text has to be read in full to determine whether the limit was exceeded, and changes from *Within Limit* to *Limit Exceeded*, and vice versa, are hard to notice. Some visual indications, such as a change in the color of the sum, when the limit is exceeded, would be helpful.

As an improvement, we would like the text color of the the sum, and the status message, to be red when the sum exceeds the limit, and to be green when it is within the limit.

Let's start off by giving an ID to the elements in which the sum and status message are displayed, so that they can be referenced from Tridash code. Surround `<?@sum ?>` in a `span` element with ID `sum` and assign the `div` element, containing the status message, the ID `status`.

```
<div><strong>A + B = <span id="sum"><?@ sum ?></span></strong></div>
<div id="status">
  <?@
    case(
        sum < limit : "Within Limit.",
        "Limit Exceeded!"
    )
  ?>
</div>
```

Let's create a node `color` which will be bound to the text color in which the sum and status message should be displayed. It should have the value `"green"` when the sum is within the limit and the value `"red"` when the sum exceeds the limit. This can be achieved by binding to a `case` functor node.

> **Note**
> The values `"green"` and `"red"` are strings, representing CSS color names.

Add the following to the Tridash code tag.

```
case(
  sum < limit : "green",
  "red"
) -> color
```

The value of the `case` functor node is `"green"` if `sum` is less than `limit` and `"red"` otherwise. The case functor node is bound to the `color` node.

The `color` node somehow has to be bound to the text color of the `sum` and `status` elements. Text color is a style attribute of an element. All style attributes are grouped under a single subnode `style` of the HTML element node. The text color is controlled by the `color` attribute, referenced using `style.color`.

The `color` node is bound to the style attributes of the elements with the following (add to the Tridash code tag):

```
color -> self.sum.style.color
color -> self.status.style.color
```

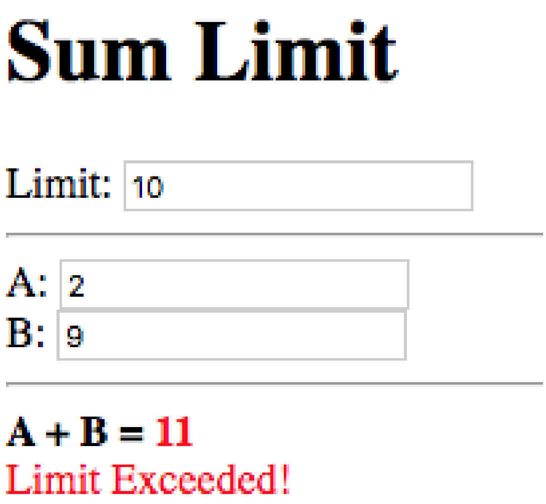
Full `ui.html` code:

ui.html

```
<?
 /import(core)

 a + b -> sum

 case (
     sum < limit : "green",
```

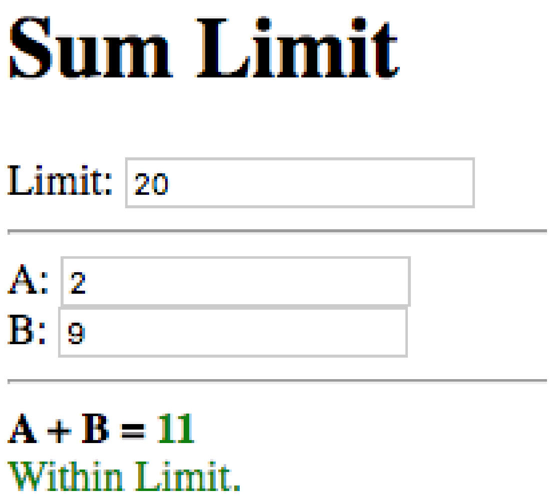
```
     "red"
 ) -> color

 color -> self.sum.style.color
 color -> self.status.style.color
?>
<!doctype html>
<html>
    <head>
        <title>Sum Limit</title>
    </head>
    <body>
      <h1>Sum Limit</h1>
      <div><label>Limit: <input value="<?@ to-int(limit) ?>"/></label></div>
      <hr/>
      <div><label>A: <input value="<?@ to-int(a) ?>"/></label></div>
      <div><label>B: <input value="<?@ to-int(b) ?>"/></label></div>
      <hr/>
      <div><strong>A + B = <span id="sum"><?@ sum ?></span></strong></div>
      <div id="status">
        <?@
          case(
              sum < limit : "Within Limit.",
              "Limit Exceeded!"
          )
        ?>
      </div>
    </body>
</html>
```

Build and run the application. Enter some values for `a`, `b` and the limit such that the sum exceeds the limit.



The status message and sum are now shown in red which provides an immediate visual indication that the limit has been exceeded.

Now increase the limit, or decrease the values of `a` and `b`:



The color of the status message and sum is immediately changed to green, which provides a noticeable indication that the limit has no longer been exceeded.

Writing your own Functions

In this tutorial you'll learn how to create your own functions, which can be used in functional bindings. Another feature which distinguishes Tridash from frameworks/toolkits, which offer bindings, is that new functions can be written in the same language, as the language in which the bindings are declared, rather than having to be implemented in a lower-level language.

Note
Only some of the example applications will be demonstrated. Visit the source code for the tutorials to try out the remaining applications.

Definition Operator

New functions, referred to as meta-nodes, are defined using the special **:** operator, which has the following syntax:

```
function(arg1, arg2, ...) : {
   declarations...
}
```

The left-hand side contains the function name (`function`) followed by the argument list in brackets, where each item (`arg1`, `arg2,...`) is the name of the local node to which the argument at that position is bound.

The right-hand side, of the **:** operator, contains the declarations making up the body of the function, which may consist of any Tridash node declaration. The value of the last node in the `declarations` list is returned by the function.

The meta-node can then be used as the operator of functor nodes, which are referred to as instances of the meta-node, declared after its definition.

Tip
The curly braces `{` and `}` are optional if the meta-node body consists of a single declaration.

Example Adding Two Numbers

```
# Add two numbers ❶

add(x, y) : x + y
```

❶ This is a comment. Comments begin with a # character and extend till the end of the line. All text within a comment is discarded.

In this example, an `add` meta-node is defined which takes two arguments, `x` and `y`, and returns their sum.

Our sum application can thus be rewritten as follows:

```
<?
 /import(core)

 # Add two numbers

 add(x, y) : x + y
?>

...

<div><label>A: <input value="<?@ to-int(a) ?>"/></label></div>
<div><label>B: <input value="<?@ to-int(b) ?>"/></label></div>

A + B is <?@ add(a, b) ?>
...
```

Node `self`

When an explicit binding to the `self` node is established inside a meta-node, the value of the `self` node is returned rather than the value of the last node in the meta-node's body.

The following is an alternative implementation of the `add` meta-node.

```
add(x, y) : {
    x + y -> self
}
```

This is particularly useful when binding to subnodes of the `self` node, which you'll learn about later.

Optional Arguments

Meta-node arguments can be designated as optional by giving the argument a default value. An optional argument is of the form `arg :value`, where `arg` is the argument node identifier and `value` is the default value, to which it is bound, if it is not provided.

Example

```
increment(n, delta : 1) : n + delta
```

In this example, the argument `delta` is optional and is given the default value 1 if it is not provided.

Examples

```
increment(n)    # delta defaults to 1
increment(n, 2) # delta = 2
```

Default values don’t have to be constants, in-fact any node expression can be used as a default value. In the case that the default value is a node, then that node will be implicitly bound to all instances of the meta-node, for which the argument is not provided.

Example: Node Default Values

```
# Increment `n` by `d`

increment(n, d : delta) : n + d
```

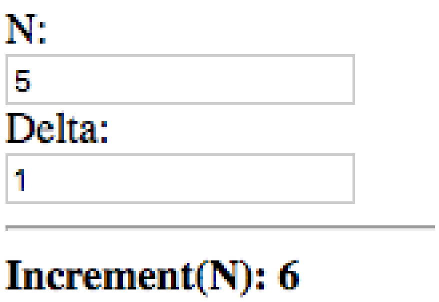
In this example the default value for the delta `d` is the value of the global node `delta`. A binding between `delta` and each instance of `increment`, for which a value for `d` is not provided, will be established.

The effect of this is demonstrated in the following example application:

ui.html

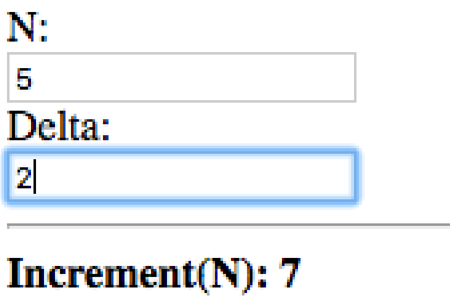
```
<?
 /import(core)

 # Increment `n` by `d`

 increment(n, d : delta) : n + d
?>
<!doctype html>
<html>
    <head>
        <title>Optional Argument Default Value</title>
    </head>
    <body>
      <h1>Optional Argument Default Value</h1>
      <div><label>N: <br/><input value="<?@ to-int(n) ?>"/></label></div>
      <div><label>Delta: <br/><input value="<?@ to-int(delta) ?>"/></label></div>
      <hr/>
      <div><strong>Increment(N): <?@ increment(n) ?></strong></div>
    </body>
</html>
```

Enter an initial value for *N* and *Delta*:



The value given to the delta (`d`) argument of `increment` is the initial value given for *Delta*, which is `1`.

Now try changing *Delta*:



The value of the `increment(n)` node is updated, with the new value of *Delta* given as the delta argument. This shows that a binding is established rather than simply taking the value of the `delta` node.

Recursive Meta-Nodes

A recursive meta-node contains an instance of itself in its definition.

The following are the classic examples of recursion:

Example: Factorial

```
factorial(n) :
    case(
        n < 1 : 1,  # Ignoring the case: n < 0
        n * factorial(n - 1)
    )
```

Example: Fibonacci Numbers

```
fib(n) :
    case(
        n <= 1 : 1,
        fib(n - 1) + fib(n - 2)
    )
```

Recursion is the means by which Tridash provides iteration. The definition of `factorial`, above, will result in the stack space being exhausted for large values of `n`. This is due to the fact that each invocation of the meta-node consumes a certain amount of stack space. Since the recursive call to `factorial` has to be evaluated before the return value of the current call can be computed, the meta-node consumes an amount of stack space proportional to the value of `n`.

If the definition is rewritten such that it is tail recursive, that is the return value of `factorial` is the return value of the recursive call, a constant amount of stack space is consumed.

Example: Tail-Recursive Factorial

```
factorial(n, acc : 1) :
    case(
        n < 1 : acc,  # Ignoring the case: n < 0
        factorial(n - 1, n * acc)
    )
```

This definition of `factorial` is tail recursive since the recursive call appears directly as the default value of the `case` expression, which is simply returned without any further operations performed on it.

In the previous implementation, the multiplication was performed on the result of the recursive call to `factorial`. In this implementation, the multiplication is performed on an accumulator argument, `acc` which is passed on to the recursive call and eventually returned when `factorial` is called with `n < 1`.

Note

Tridash supports general *tail call optimization* for mutually recursive meta-nodes.

Nested Meta-Nodes

A meta-node may contain other meta-nodes inside its definition. These meta-nodes may only be used within the body of the meta-node and shadow meta-nodes, declared in the enclosing scope, with the same identifiers.

With nested meta-nodes we can rewrite our previous tail-recursive `factorial` meta-node without having to expose the accumulator argument `acc`, which is an implementation detail.

Example: Factorial with nested iter meta-node

```
factorial(n) : {
    iter(n, acc) : {
        case(
            n < 1 : acc,  # Ignoring the case: n < 0
            iter(n - 1, n * acc)
        )
    }

    iter(n, 1)
}
```

The computation of the factorial is implemented in the nested tail-recursive meta-node `iter`. The `factorial` meta-node simply calls this meta-node with the initial value for the accumulator.

Local Nodes

Nodes which appears as the *target* (observer) of a binding, declared within the body of a meta-node, are local to the meta-node's body and may only be referenced within it. These may be used to store intermediate results or to break up complex expression into multiple nodes.

Example: Average

```
average(a, b) : {
    sum <- a + b      ❶
    sum / 2
}
```

❶ Node `sum` is the binding *target* in this declaration.

In this example a local node `sum` is created, since it is bound (as the *target*) to the value of `a + b`. The value returned by `average` is the value of `sum` divided by 2.

Referencing Outer Nodes

A meta-node may reference nodes declared in the global scope or the enclosing scope(s) containing the meta-node definition. This creates a binding between the referenced node and each instance of the meta-node. The net result is that whenever the value of the referenced node changes, the value of the instance is recomputed. In essence a reference to an outer node can be thought of as an additional hidden argument.

> **Tip**
> An outer node with the same identifier as a local node can be referenced with the `..` operator, e.g. `..(x)`.

Outer node references can be demonstrated by changing the definition of `increment`, in the *Increment* Application developed earlier in this tutorial, to the following:

Increment with reference to delta

```
increment(n) : n + delta
```

The `d` argument has been removed and replaced with `delta` in the body.

Repeat the same experiment, changing the delta, you should observe the same results.

Fun Example: Simple Meter

In this example we'll be developing an application which displays a simple meter, representing a quantity, which changes color as the quantity approaches the maximum.

Let's start off with the following HTML interface:

ui.html

```
<!doctype html>
<html>
    <head>
      <title>Simple Meter</title>
      <style>
        .meter-box {
            margin-top: 5px;
            width: 200px;
            height: 1em;
            border: 1px solid black;
        }
        .meter-bar {
            height: 100%;
        }
      </style>
    </head>
    <body>
      <h1>Simple Meter</h1>
      <div><label>Maximum: <input value="<?@ to-int(maximum) ?>"/></label></div>
      <div><label>Quantity: <input value="<?@ to-int(quantity) ?>"/></label></div>
      <div class="meter-box">
        <div id="meter" class="meter-bar"></div>
      </div>
    </body>
</html>
```

Note

The file contains a few CSS class definitions for styling the elements which display the meter, located at the bottom of the file.

The interface consists of two input fields for entering the values for the *Maximum* and *Quantity*, which are bound to the nodes `maximum` and `quantity`, respectively.

We'd like the meter to be displayed in a color which is in between green (empty) and red (full) depending on where the value of the quantity lies between 0 and the maximum.

First we'll write a utility meta-node `lerp` for linearly interpolating between two values:

Meta-Node lerp

```
lerp(a, b, alpha) : a + alpha * (b - a)
```

The value returned by `lerp` is the value between `a` and `b` proportional to where `alpha` lies between `0` and `1`.

This meta-node will be used to interpolate between green and red depending on where the quantity lies between 0 and the maximum.

We can compute the value for `alpha` by dividing the value for the quantity by the maximum.

```
scale <- quantity / maximum
```

Note

This assumes that `maximum` is not 0.

Before we perform the interpolation, we need to make sure that `scale` is a value between 0 and 1. Let's write another utility meta-node `clamp` which clamps a value to a given range.

Meta-Node clamp

```
clamp(x, min, max) :
    case (
        x < min : min,
        x > max : max,
        x
    )
```

This meta-node returns the value of its first argument `x` if it is between `min` and `max`, otherwise returns `min` if `x` is less than `min`, or `max` if `x` is greater than `max`.

We can amend the computation of `scale` such that it does not exceed `0` and `1`, by using the `clamp` meta-node.

```
scale <- clamp(quantity / maximum, 0, 1)
```

Finally we can interpolate between the two colours. We'll be using the HSL (Hue Saturation Luminance) colorspace, and interpolating in the *Hue* component.

Note

The HSL, rather than the RGB, colorspace was used as it provides better interpolation results.

```
hue <- lerp(120, 0, scale)
```

`hue` is bound to a value interpolated between green (Hue 120) and red (Hue 0) with the value of `scale` as the interpolation coefficient.

Before we bind the interpolated color to the color of the meter, let's write another utility meta-node which takes values for the hue, saturation and luminance components and produces a CSS HSL color string.

Meta-Node make-hsl

```
make-hsl(h, s, l) :
    format("hsl(%s,%s%%,%s%%)", h, s, l)
```

Tip

The `format` meta-node produces a string in which `%s` placeholders in the format string (the first argument) are replaced with the values of the corresponding arguments (following the format string). `%%` placeholders are replaced with literal `%` characters. `format("Hello %s %s.", "John", "Smith")` produces the string "Hello John Smith.", as the first `%s` is replaced with `"John"` and the second `%s` is replaced with `"Smith"`.

We can now generate a valid CSS color string using `make-hsl` that we'll bind to the color of the meter element, which is the element with ID `meter`.

```
self.meter.style.backgroundColor <-
    make-hsl(hue, 90, 45)
```

Tip

The `backgroundColor` style attribute references the background color of an element.

The constant values `90` and `45` have been chosen for the saturation and luminance components.

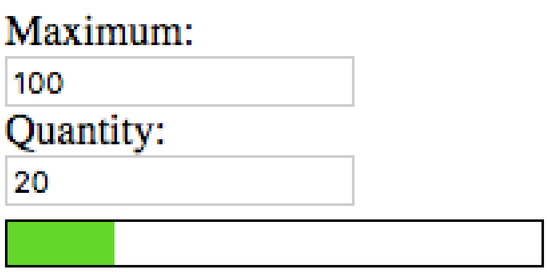
The last thing we need to do is adjust the width of the meter depending on the quantity value. We'll simply multiply the value of `scale` by 100, to convert it to a percentage (indicating it should occupy that percentage of the width of its parent element), and bind it to the meter element's width attribute.

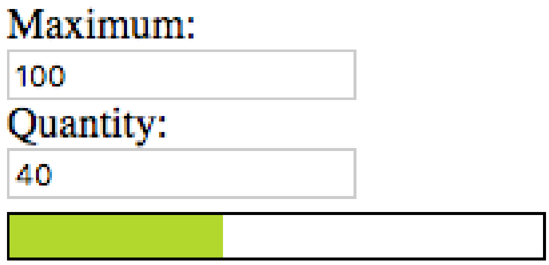
```
format("%s%%", scale * 100) -> self.meter.style.width
```

Our application is complete. Add the following Tridash code tag to the top of the `ui.html` file.

```
<?
 /import(core)

 # Utilities

 lerp(a, b, alpha) : a + alpha * (b - a)

 clamp(x, min, max) :
     case (
         x < min : min,
         x > max : max,
         x
     )

 make-hsl(h, s, l) :
     format("hsl(%s,%s%%,%s%%)", h, s, l)


 # Application Logic

 scale <- clamp(quantity / maximum, 0, 1)

 hue <- lerp(120, 0, scale)

 self.meter.style.backgroundColor <-
     make-hsl(hue, 90, 45)

 format("%s%%", scale * 100) -> self.meter.style.width
?>
```

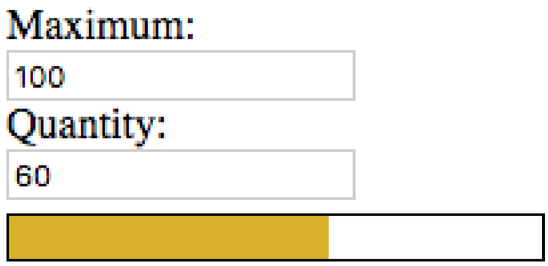
Build and run the application, and enter some values for the quantity and maximum, such that the quantity is less than half the maximum.

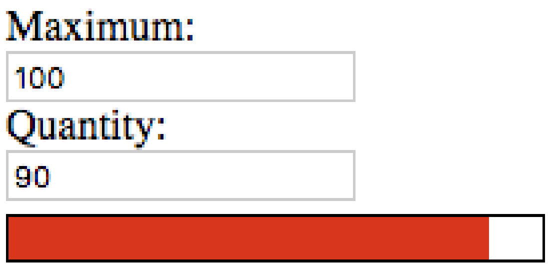




The meter is mostly empty and displayed in a green color.

Now increase the quantity such that it is greater than half the maximum.





The meter is more than half full and its color approaches red as the quantity approaches the maximum.

Subnodes

You've already made use of subnodes in the previous tutorials, when binding to attributes of HTML elements. Now we'll explores subnodes in depth.

A subnode is a node which references a value out of a dictionary of values stored in a parent node.

Subnode Syntax

```
parent.key
```

The left hand side of the subnode `.` operator is the parent node expression and the right hand side is the key identifying the dictionary entry.

Note

`key` is interpreted as a literal symbol rather than a node identifier.

A dictionary can be created in a node by binding to a subnode of the node.

Example

```
"John" -> person.name
"Smith" -> person.surname
```

In this example, the value of the node `person` is a dictionary with two entries

`name` Bound to the string constant “John”.

`surname` Bound to the string constant “Smith”.

Example: Color Object

The meter application developed during the previous tutorial was a bit of mess with the various color components scattered through the code.

To change the colors you’d first have to change the hue components, in the following code:

```
hue <- lerp(120, 0, scale)
```

It isn’t clear what the numbers `120` and `0` are supposed to be or which number corresponds to the hue component of which color.

To change the luminance and saturation components, you’d have to modify the following:

```
self.meter.style.backgroundColor <-
    make-hsl(hue, 90, 45)
```

There is also no interpolation of the saturation or luminance components.

The code can be made significantly more readable and maintainable by making use of a dedicated *color object*.

We’ll create a meta-node `Color` which takes the three color components as arguments and returns a dictionary storing the components under the entries: `hue`, `saturation` and `luminance`.

How are we going to return a dictionary from a meta-node? We can create a dedicated local node, in which the dictionary is created, such as the following:

```
Color(hue, saturation, luminance) : {
    hue -> color.hue
    saturation -> color.saturation
    luminance -> color.luminance

    color
}
```

Or we can simply bind to subnodes of the `self` node.

Meta-Node Color

```
Color(hue, saturation, luminance) : {
    hue -> self.hue
    saturation -> self.saturation
    luminance -> self.luminance
}
```

The dictionary returned by `Color` is how colors will be represented in our application. Let's create color objects for the two colors and bind them to nodes:

```
color-empty <- Color(120, 90, 45)
color-full  <- Color(0, 90, 45)
```

Tip

`color-empty` and `color-full` are examples of constant nodes as their values are not dependent on other nodes and are thus effectively constant.

Rather than interpolating between the components of `color-empty` and `color-full` in the global scope, we can create a meta-node that takes two colors and the alpha coefficient, and returns the interpolated color.

Meta-Node lerp-color

```
lerp-color(c1, c2, alpha) :
    Color(
        lerp(c1.hue, c2.hue, alpha),
        lerp(c1.saturation, c2.saturation, alpha),
        lerp(c1.luminance, c2.luminance, alpha)
    )
```

The `lerp-color` meta-node simply creates a new color, using the `Color` meta-node, with each component interpolated between the two colors, using `lerp`.

We can use this to easily interpolate between the colors:

```
color <- lerp-color(color-empty, color-full, scale)
```

To convert the Color object to a CSS color string we have to pass each component to `make-hsl` as an individual argument like so:

```
make-hsl(color.hue, color.saturation, color.luminance)
```

However, the internal representational details of the color are leaking into the application logic. All it takes is to accidentally pass a single component twice or pass the components in the wrong order and there is a bug.

To rectify this we can rewrite `make-hsl` to take a Color object or we can bind a subnode of the Color object to the CSS color string.

Modify `Color` to the following:

```
Color(hue, saturation, luminance) : {
    hue -> self.hue
    saturation -> self.saturation
    luminance -> self.luminance

    make-hsl(hue, saturation, luminance) -> self.hsl-string
}
```

We've added a new declaration to `Color` which binds the `hsl-string` subnode of `self` to the CSS HSL color string, created using `make-hsl`. Since the values of nodes are only evaluated if they are used, and subnodes are no different, the value of the subnode `hsl-string` will only be computed for the final `color` object, not the `color-empty` and `color-full` objects.

Tip

If you'd like to make the code even neater you can move the definition of the `make-hsl` meta-node inside the `Color` meta-node.

The interpolated color can be bound to the meter's background color with the following:

```
color.hsl-string -> self.meter.style.backgroundColor
```

We now have a new more readable and maintainable version of the meter application. Replace the Tridash code tag with the following:

```
<?
 /import(core)

 # Utilities

 lerp(a, b, alpha) : a + alpha * (b - a)

 clamp(x, min, max) :
     case (
         x < min : min,
         x > max : max,
         x
     )

 make-hsl(h, s, l) :
     format("hsl(%s,%s%%,%s%%)", h, s, l)

 Color(hue, saturation, luminance) : {
     hue -> self.hue
     saturation -> self.saturation
     luminance -> self.luminance

     make-hsl(hue, saturation, luminance) -> self.hsl-string
 }

 lerp-color(c1, c2, alpha) :
     Color(
         lerp(c1.hue, c2.hue, alpha),
         lerp(c1.saturation, c2.saturation, alpha),
         lerp(c1.luminance, c2.luminance, alpha)
     )


 # Application Logic

 color-empty <- Color(120, 90, 45)
 color-full  <- Color(0, 90, 45)

 scale <- clamp(quantity / maximum, 0, 1)

 color <- lerp-color(color-empty, color-full, scale)


 color.hsl-string -> self.meter.style.backgroundColor

 format("%s%%", scale * 100) -> self.meter.style.width
?>
```

Compared to the previous version, this version has a number of benefits:

1. It is clearly visible where the two colors are defined, and thus can be changed easily.
2. The color components are kept in a single place rather than being scattered throughout the code.
3. All components of the colors are interpolated.

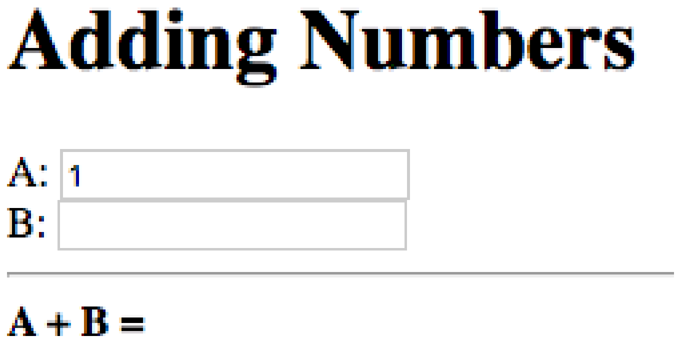
Error Handling with Failure Values

Up till this point we have completely ignored the issue of what happens if the user provides invalid input. In this tutorial, failure values and their use in handling errors will be introduced.

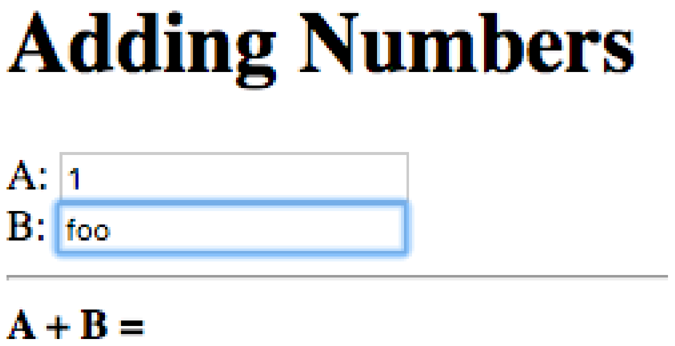
Invalid Input

First let's investigate more closely what happens when an invalid value is entered by the user. Let's try it out with the sum application we wrote in Section 2.

You may have noticed that nothing happens if a number is only entered in one of the fields:

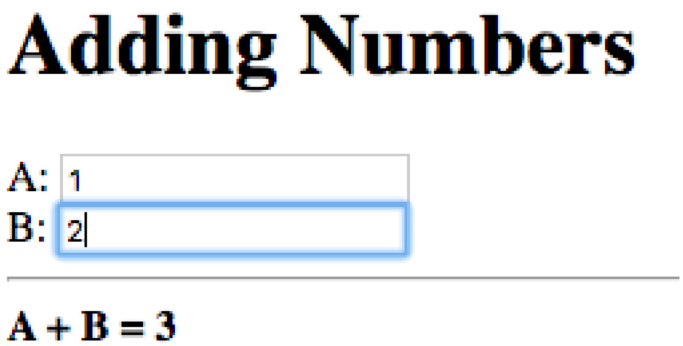


Let's enter an invalid value for *B*, and see what happens:



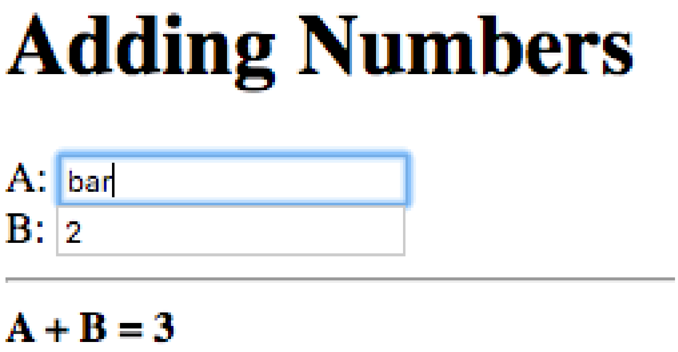
Again nothing. Is there something wrong with application?

Let's change *B* to a valid number:



Now we get the result of the addition, `3`. The application resumed its normal operation when valid input is entered.

What will happen if we change one of the fields to an invalid value, let's try changing *A* this time:



No change in the result of `3`. It appears the application does not change the result if invalid input was entered. This demands an explanation.

Failure Values

What's really going on under the hood is that when a value, which is not a valid number, is entered in one of the input fields, the node bound to that field is set to a *failure value*.

A failure value is a special type of value which, when evaluated, terminates the evaluation of the node, by which it was evaluated, and the node's value is set to the failure value. Failure values represent the failure of an operation, the absence of a value or special classes of values.

In the sum application, a failure value is returned by the `to-int` meta-node, when the argument is a string which does not contain a valid integer. Thus `to-int(a)` evaluates to a failure value if the value entered in the input field for *A* does not contain a valid integer.

Note
Remember that `to-int(a)` is bound, as the target, to the value entered in the text input field.

The observer of `to-int(a)` is `a`, and is thus set to the failure value returned by `to-int`. Node `a + b` evaluates node `a`, thus evaluating the failure value. This results in the computation of the sum (`a + b`) being terminated and node `a + b`, and its observer `sum`, being set to the failure value.

By default when a node, bound to a user interface element, evaluates to a failure value, the user interface is not updated. As a result the application appears to be doing nothing.

Handling Failures

Whilst the current behaviour of the application is a step up from crashing or producing garbage results, it does not provide any indication to the user that the input entered was invalid. This is confusing to the user as the application appears to not be working properly. Proper error handling should be in place.

The `core` module provides a handy utility meta-node `fails?`, which returns true if its argument node evaluates to a failure, and false otherwise. This can be used to detect failures in our application and display an appropriate error message.

Tip
A related utility meta-node `?`, also from the `core` module, returns true if its argument does not evaluate to a failure.

We need to detect failures in the a and b nodes which are bound to the values of the input fields for *A* and *B*, respectively. This can be achieved using the expression `fails?(a)` for a and `fails?(b)` for b.

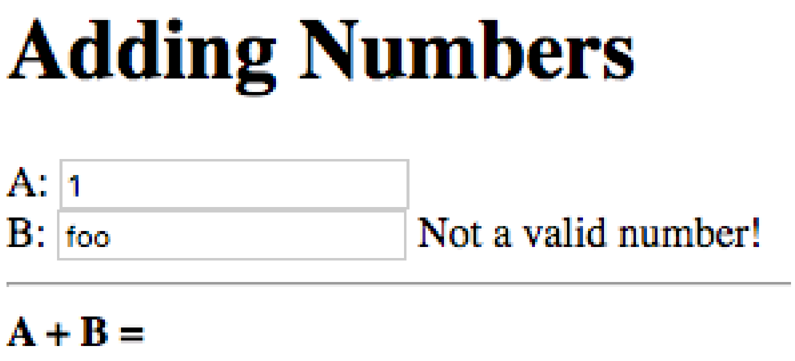
We would like to display a message, indicating that the input entered was invalid, next to the field where invalid input was entered. This can be achieved using a `case` expression. The following is the `case` expression for a:

```
case(
    fails?(a) : "Not a valid number!",
    ""
)
```

The `case` expression returns the constant string “Not a valid number!”, if `fails?(a)` is true, that is a evaluates to a failure, otherwise it returns the empty string. To display the error message next to the field for *A*, we can simply place the entire `case` expression in an inline node declaration, between `<?@...?>` next to the field. We can do the same for *B*, substituting a with b, to get an error indication for *B* as well.

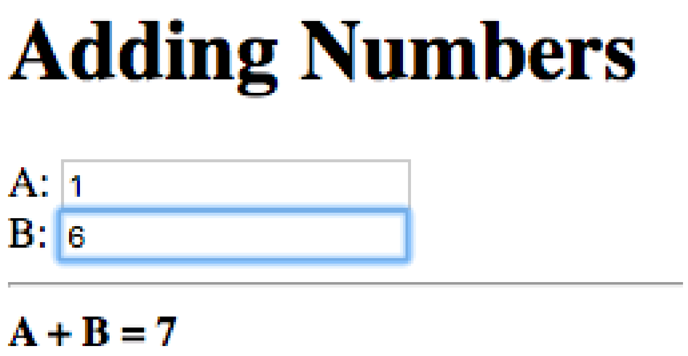
That’s it we have added error handling to an existing application without having to make fundamental changes to our application logic. In-fact the addition of error handling was as simple as adding new UI elements.

Let’s try it out. Build and run the application and enter an invalid value in one of the input fields:



The message “Not a valid number!” is displayed next to the field containing the invalid value, *B* in this case.

Now correct the invalid value, to a valid number:



The message disappears and the sum is computed.

Cleaning Up

The error handling logic, added in the previous section, can do with some cleaning up.

- The error message is duplicated next to both fields. If we'd like to change the message we'd have to make sure we've changed it in both places.
- The `case` expression is identical for both fields with the only difference being the node. If we change the error handling logic, to display a different message, we'd have to edit both the `case` expressions.

The case expression can be extracted into a meta-node, let's call it `error-message` which takes the node as input and returns the appropriate error message.

Meta-Node error-message

```
error-message(value) :
    case(
        fails?(value) : "Not a valid number!",
        ""
    )
```

Add this definition to the top of the Tridash code tag.

We can now replace the `case` expressions, inside the inline node declarations with the following for field *A*:

```
error-message(a)
```

and the following for field *B*:

```
error-message(b)
```

Changes to the error message and error handling logic are now much easier to implement as only the definition of the `error-message` meta-node needs to be changed.

Initial Values

You may have noticed that the error messages are not displayed initially, when the input fields are empty. Similarly no visible result is observed until a value is entered in both fields. You're probably wondering why this is so, as an empty string is certainly not a valid integer. In-fact, if you first enter a valid integer in a field, and then change its value to empty, the error message will be displayed.

The problem is that the nodes `a` and `b` are not given initial values. As a result the value of the `error-message(a)` node, and the corresponding node for `b`, is not computed until `a` is given its first value. But then what happens when the node `a + b` is updated after a value is entered in the first field, *A*, only? Since only the dependency `a`, of `a + b` has been given a value, `a + b` does not have a value for `b` and thus the value it uses for `b` defaults to a failure. To solve this problem we can give initial values to `a` and `b`.

An explicit binding in which the *source* is a literal constant and the *target* is a node is interpreted as giving the node an initial value, equal to the constant.

The following assigns an initial value of 1 to `a` and 2 to `b`:

Example

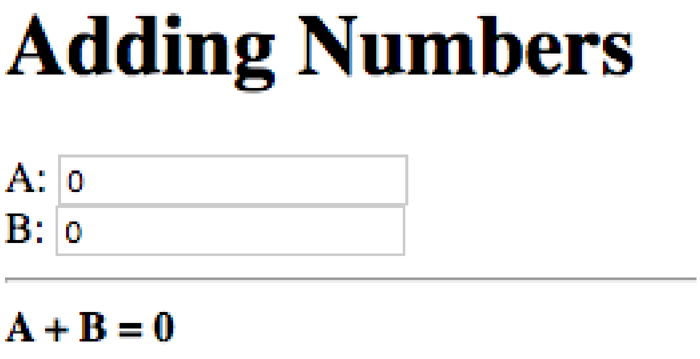
```
1 -> a
2 -> b
```

The setting of the initial values is treated as an ordinary value change from the default failure value to the given initial value, which occurs immediately after the application is launched. As a result, the values of the node's observers are updated. In this case the nodes: `a + b`, `error-message(a)` and `error-message(b)` will be updated.

In our application, let's give both `a` and `b` an initial value of `0`. Add the following to the Tridash code tag at the top of the file:

```
0 -> a
0 -> b
```

Build and run the application:



Both fields are initialized to `0` and the sum of `0` is displayed.

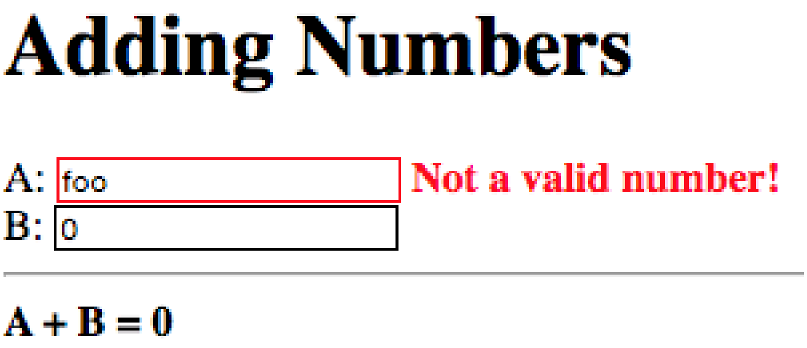
Experiment with changing the node's initial values and even try setting them to invalid integers.

Note
You may be wondering how it is that giving an initial value to the nodes `a` and `b` affects the values of the text input fields. This is due to the fact that there is a two-way binding between `a` and the value of the input element for *A*, and between `b` and the value of the input element for *B*.

Exercise

As an exercise make the color of the border, or alternatively the background color, of the input element change to red when an invalid value is entered in it.

Try to achieve something similar to the following:



Note
Some CSS styling rules have also been added to change the text color of the error messages to red, this is not part of the exercise.

Tip
To change the border color of an element bind to the `style.borderColor` attribute of the element node.

Failure Types

The error handling tools we've seen so far have one serious shortcoming, there is no means for identifying the cause of the error. In the application, which we augmented with error handling in the previous tutorial, we don't check at all what the cause of the failure is. Instead, we simply assumed that a failure value means invalid input was entered. Whilst this is the case in our simple application, it is not the case for more complex real world applications where there are many potential sources of errors.

Identifying the cause of Failures

Each failure value has an associated type, which is a value that identifies the cause of the failure. The *failure type* can be obtained using the `fail-type` meta-node from the `core` module. If the argument of `fail-type` evaluates to a failure, the meta-node returns its type, otherwise if the argument does not evaluate to a failure or evaluates to a failure without a type, the meta-node returns a failure.

The meta-node `fail-type` is a bit clunky to use as it, itself, returns a failure if the argument does not evaluate to a failure value. The utility `fail-type?` meta-node, also from the `core` module, takes two arguments, a value and a failure type, and returns true if the value evaluates to a failure of that type.

A value used as a failure type is generally bound to a constant node, which is used in place of the raw value. An accompanying node, with the same identifier but with a trailing `!` is bound to a failure of the type.

Example: Checking Failure type in *Adding Numbers* Application

The type of the failure returned by `to-int`, when given a string that does not contain a valid integer, is designated by the node `Invalid-Integer`, from the `core` module. The node `Invalid-Integer!` is bound to a failure of type `Invalid-Integer`.

We can use the `fail-type?` meta-node to explicitly check whether the failure is of the type `Invalid-Integer`. Simply replace `fails?(value)` with `fail-type?(value, Invalid-Integer)` in the definition of the `error-message` meta-node.

Improved error-message Meta-Node

```
error-message(value) :
    case(
        fail-type?(value, Invalid-Integer) : "Not a valid number!",
        ""
    )
```

The new implementation returns the string "Not a valid number!" only for errors caused by invalid input being entered. It returns the empty string for errors of any other type.

Creating Failure Values

Failures are limited in use if they can only be created by builtin meta-nodes. You can create your own failure values using the `fail` meta-node, which takes one optional argument — the type of the failure. If the type argument is not provided, a failure without a type is created.

Example

```
# Creates failure with no type
fail()

# Creates a failure with type 'My-Type'
fail(My-Type)
```

Example: Positive Numbers Only

Suppose for some reason, we'd like to limit the numbers being added, in the *Adding Numbers* application, to positive numbers. It could be that the numbers represent amounts for which negative values do not make sense in the context of the application.

Let's write a meta-node, `validate`, which takes an integer value and returns that value if it is greater than or equal to zero. Otherwise it returns a failure of a user-defined type designated by the node `Negative-Number`.

Meta-Node validate

```
validate(x) :
    case(
        x >= 0 : x,
        fail(Negative-Number)
    )
```

If the argument `x` is greater than or equal to zero it is returned directly, otherwise a failure, created using the `fail` meta-node, of type designated by `Negative-Number` is returned.

Now let's bind the `Negative-Number` node to a value, which uniquely identifies the failure. For now let's choose the value `-1`. While we're at it let's also define the `Negative-Number!` meta-node which is simply bound to a failure of type `Negative-Number`.

Failure Type `Negative-Number `

```
Negative-Number  <- -1
Negative-Number! <- fail(Negative-Number)
```

We can simplify `validate` by substituting `fail(Negative-Number)` with `Negative-Number!`:

Simplified validate Meta-Node

```
validate(x) :
    case(
        x >= 0 : x,
        Negative-Number!
    )
```

Note
It does not matter whether you place the binding declarations of the nodes `Negative-Number` and `Negative-Number!` before or after the definition of `validate`.

To incorporate this in our application, we have to change the nodes, to which the input fields are bound, from `a` and `b` to `input-a` and `input-b`.

Replace `a` with `input-a`, in the text field for *A*, and `b` with `input-b` in the text field for *B*.

```
...
<label>A: <input value="<?@ to-int(input-a) ?>"/></label>
...
<label>B: <input value="<?@ to-int(input-b) ?>"/></label>
...
```

Also change the setting of initial values such that they are set on nodes `input-a` and `input-b` rather than `a` and `b`.

```
0 -> input-a
0 -> input-b
```

Now we're going to bind `a` to the result of `validate` applied on `input-a` and we're going to bind `b` to the result of `validate` applied on `input-b`.

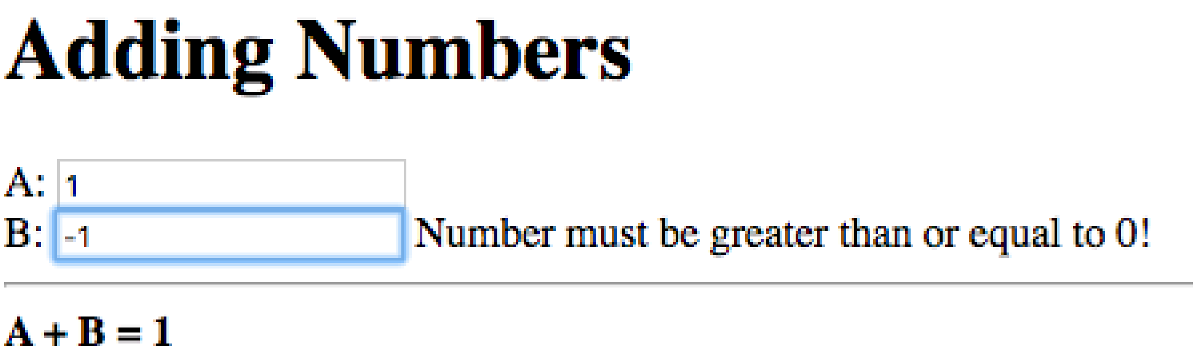
```
a <- validate(input-a)
b <- validate(input-b)
```

Finally let's update the `error-message` meta-node to return "Number must be greater than or equal to 0!" in the case that the failure is of type `Negative-Number`.

Updated error-message Meta-Node

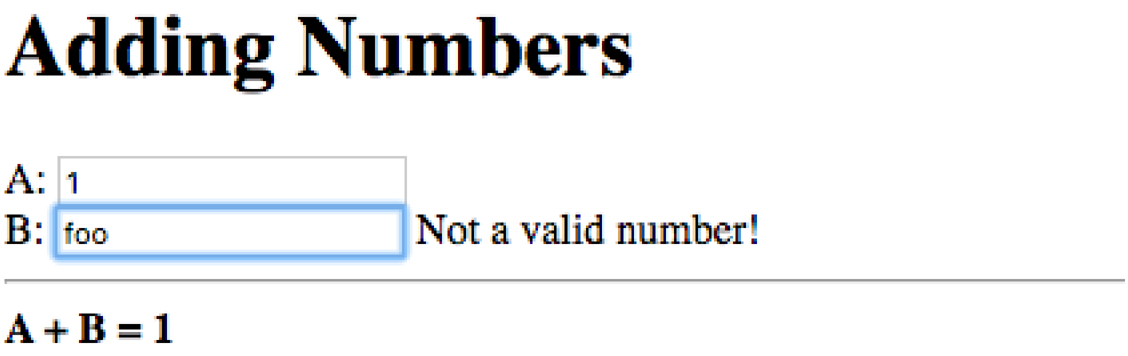
```
error-message(value) :
    case(
        fail-type?(value, Invalid-Integer) :
            "Not a valid number!",
        fail-type?(value, Negative-Number) :
            "Number must be greater than or equal to 0!",
        ""
    )
```

Build and run the application and enter a positive number in one field and a negative number in the other:



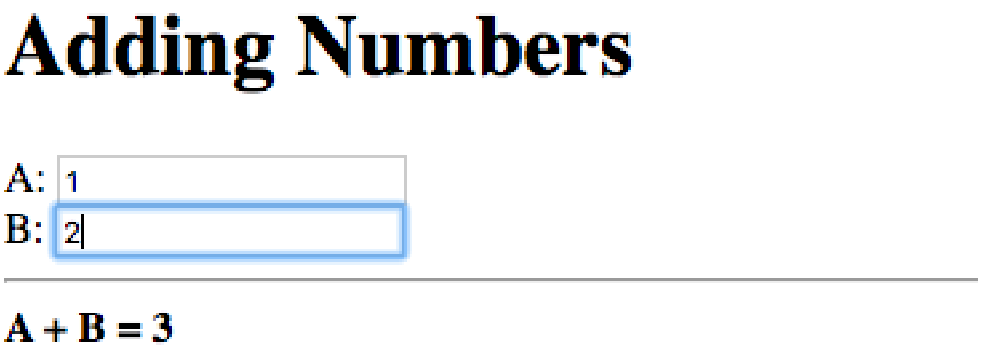
The error message, explaining that a positive number (or zero) must be entered, is displayed next to the field where the negative number was entered, *B* in this case. The result of the addition with the new numbers entered is not displayed, instead the previous result is retained, as expected.

Change the negative number to an invalid number:



The error message changes to "Not a valid number!" and the displayed sum is unchanged, as in the previous versions.

Now change the value to a valid positive number:



The error message disappears and the new sum is displayed.

Proper Failure Types

There is one issue with the application we've just developed. There is no guarantee that the arbitrary constant `-1` uniquely represents a failure of type `Negative-Number`. If all failure types used arbitrary integer constants, there is no guarantee that `-1` doesn't already represent a builtin failure type, such as `Invalid-Integer`. Whilst it so happened to work, it is certainly not robust, especially when bringing in third party libraries.

A value, which is guaranteed to be unique, can be obtained by taking a reference to the *raw node object* of `Negative-Number`.

References to the raw node object, of a node, can be obtained using the `&` special operator, which takes the identifier of the node as an argument. Raw node references are mostly useful when writing macros, which you'll learn about in a later tutorial. For now all that you need to know is that this value can serve as the failure type, i.e. can be compared using `=`, and is guaranteed to be unique.

Replace the binding declaration for `Negative-Number` with the following:

Proper Negative-Number Failure Type

```
Negative-Number  <- &(Negative-Number)
```

And now we have a robust way of distinguishing between failures originating from `to-int`, due to the input fields not containing valid integers, and errors originating from our own application logic.

Target Node Transforms

Wow, we had to make so many fundamental changes to our code just to implement a minor change in the input accepted by the application. We had to:

1. Add the nodes `input-a` and `input-b`, for which we had to come up with meaningful identifiers.
2. Change the input fields to be bound to `input-a` and `input-b` rather than `a` and `b`.
3. Change the initial values to be assigned to `input-a` and `input-b` rather than `a` and `b`.
4. Bind `a` to `validate(input-a)` and `b` to `validate(input-b)`.

This is contrary to "simply adding new UI elements" which was the case when we introduced error handling. We can do better.

Notice that a lot of the code we added was simply repetitive binding boilerplate code, which is the same for both `a` and `b`. It would be nice if we could somehow abstract it away and not have to write the same code for both nodes. Luckily, there is a way.

Remember, from the second tutorial, that some meta-nodes, such as `to-int`, are special in that a two-way binding is established between the meta-node instance and the argument node. This allows instances of the meta-node to also appear as targets of bindings.

Refresher Example

```
# The following
a -> to-int(b)

# Is equivalent to
to-int(a) -> b
```

It turns out `to-int` is not so special as we can do the same for our own meta-nodes by setting the `target-node` attribute.

Node Attributes

Node attributes are simply key-value pairs associated with a node, which control various compilation options. Attributes are set using the special `/attribute` operator:

/attribute Operator Syntax

```
/attribute(node, key, value)
```

This sets the attribute of `node` with key `key` to the value `value`.

Examples

```
# Set value of attribute 'my-attribute' to 1
/attribute(a, my-attribute, 1)

# Set value of attribute 'akey' to literal symbol 'raw-id'
/attribute(b, "akey", raw-id)
```

> **Important**
> `key` and `value` are interpreted as literal symbols rather than references to the values of nodes. Attribute keys are case insensitive and there is no difference between raw symbols and string keys. The following keys `key`, `Key`, `"key"` and `"kEy"` all refer to the same attribute.

> **Important**
> Node attributes do not form part of a runtime node's state.

Attribute `target-node`

The `target-node` attribute determines, when set, the meta-node which is used as the binding function of the binding in the reverse direction, from a meta-node instance to the meta-node arguments.

As an example, a meta-node `f` with its `target-node` attribute set to `g` results in the following:

Example

```
/attribute(f, target-node, g)

# The following
a -> f(b)

# Is equivalent to
g(a) -> b
```

In the example above the `target-node` attribute of `f` is set to `g`. Thus the declaration `f(b)` also results in the binding `g(f(b)) -> b` being created.

The meta-node `to-int` simply has its `target-node` attribute set to itself, which is why it performs the same function, when it appears as the target of a binding, as when it appears as the source of a binding.

Tip

The `to-int` meta-node performs the same function as the `int` meta-node however the difference is that when an instance of `int` appears as the target of a binding, pattern matching (which will be introduced in a later tutorial) is performed, whereas `to-int` simply performs the same function. `int` has not been mentioned till this point to avoid creating confusion as to what's the difference between it and `to-int`.

Target-Node for own Meta-Nodes

Our code can be simplified considerably by allowing a meta-node, which performs the additional input validation, to be bound (as the target) to the values in the input field. Let's first write that meta-node, called `valid-int` which is responsible for converting an input string to an integer and ensuring that the resulting integer is greater than or equal to zero. In essence this meta-node combines `to-int`, we'll use `int` this time, and `validate`.

Meta-node valid-int

```
valid-int(value) : {
    x <- int(value)
    validate(x)
}
```

In order to allow the node to appear as the target of a binding, and still perform the same function, let's set its `target-node` attribute to itself:

```
/attribute(valid-int, target-node, valid-int)
```

Now we can bind the contents of the input fields directly to an instance of the `valid-int` meta-node. In-fact, we can place the `valid-int` instance directly in an inline node declaration.

Replace `to-int(input-a)` with `valid-int(a)`, and the same for `b`, in the input fields as follows:

```
<label>A: <input value="<?@ valid-int(a) ?>"/></label>
<label>B: <input value="<?@ valid-int(b) ?>"/></label>
```

The nodes `input-a` and `input-b` can be removed, as well as the following declarations:

```
 a <- validate(input-a)
 b <- validate(input-b)
```

The initial values of `0` can once again be given to the nodes `a` and `b` rather than `input-a` and `input-b`.

```
 0 -> a
 0 -> b
```

The following is the full content of the Tridash code tag.

```
/import(core)

# Error Reporting

error-message(value) :
    case(
        fail-type?(value, Invalid-Integer) :
            "Not a valid number!",
        fail-type?(value, Negative-Number) :
```

```
            "Number must be greater than or equal to 0!",
        ""
    )

# Input Validation

Negative-Number  <- &(Negative-Number)
Negative-Number! <- fail(Negative-Number)

validate(x) :
    case(
        x >= 0 : x,
        Negative-Number!
    )

valid-int(value) : {
    x <- int(value)
    validate(x)
}

/attribute(valid-int, target-node, valid-int)

# Initial Values

0 -> a
0 -> b
```

Compared to the previous version, the only modifications are in the `error-message` meta-node, the inline bindings in the input fields and the addition of the `validate` and `valid-int` meta-nodes along with the `Negative-Number` failure type. This version, however, did not require the addition of new nodes or modifying the bindings comprising the core application logic. Changing the input validation logic was simply a matter of substituting `to-int` with `valid-int` in the bindings to the input field values.

Contexts

Throughout these tutorials, we've glossed over two-way bindings without going into much detail of how they work, yet they were a vital component of every application as the bindings to the UI elements have all been two-way bindings.

Each node has a number of *contexts* which store information about how to compute the node's value, i.e. what function to use and what dependencies are operands to the function. The *active* context of a node, at a given moment in time, is the context which is used to compute the node's value. In general, a context is *activated* when the value of an operand node of the context changes. By default, a node context is created for each dependency of a node which was added by an explicit binding.

Example

```
a -> x # Context created for dependency `a`
b -> x # Context created for dependency `b`
c -> x # Context created for dependency `c`
```

In this example node `x` has three contexts one for each of its dependency nodes, `a`, `b` and `c`, to which it is bound explicitly.

An implicit binding between a meta-node instance and the meta-node arguments does not result in the creation of a context for each operand.

```
a + b
```

Nodes `a` and `b` are implicitly added as dependencies of `a + b` however they are added as operands to the same context with the + function.

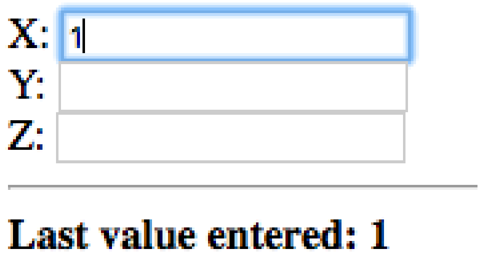
The following application demonstrates how different contexts are activated, when the values of their operand nodes change.

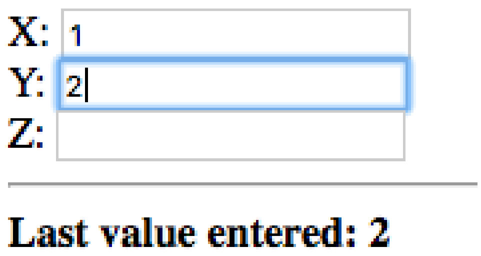
ui.html

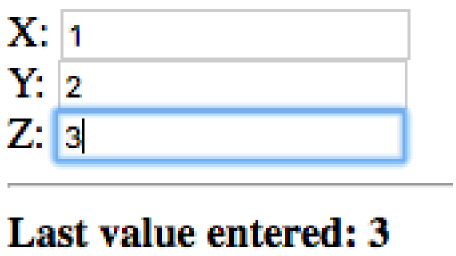
```
<?
 x -> node
 y -> node
 z -> node
?>
<!doctype html>
<html>
    <head>
        <title>Node Contexts</title>
    </head>
    <body>
      <div><label>X: <input value="<?@ x ?>"/></label></div>
      <div><label>Y: <input id="b" value="<?@ y ?>"/></label></div>
      <div><label>Z: <input value="<?@ z ?>"/></label></div>
      <hr/>
      <div><strong>Last value entered: <?@ node ?></strong></div>
    </body>
</html>
```

This is a simple application consisting of three text input fields bound to nodes `x`, `y` and `z`. Nodes `x`, `y` and `z` are each explicitly bound to `node`, the value of which is displayed below the fields.

Let's enter a value in each field and see what happens. Observe the value displayed below the fields after each change:

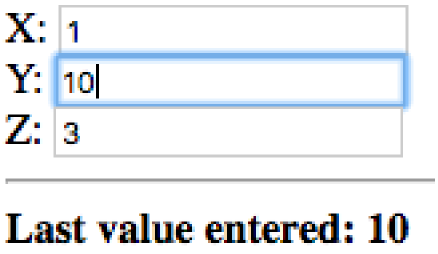






Notice that after each change, the value that was just entered is displayed.

Now let's try changing the values of the fields which were edited previously:



In this case the value of the second field, *Y*, was changed to 10 and that value was immediately displayed below the fields.

The value of the field that was changed last is displayed. To understand why this is so, let's examine the sequence of steps taken when a value is entered in the *X* field.

1. The value of `x`, which is bound to the value in the *X* field, is updated.
2. The context corresponding to the binding `x -> node` is activated due to the value of `x` being updated.
3. The value of `node` is updated to the value of `x`.

Contexts make two-way bindings possible:

Example

```
input1 -> a

# Two-way binding
a -> b; a -> b

input2 -> b
```

> **Tip**
> The `;` character separates multiple declarations written on a single line.

`a` has two contexts corresponding to dependency nodes `input1` and `a` (which is also an observer). `b` has two contexts corresponding to dependency nodes `input2` and `a`.

When `input1` is changed, the contexts corresponding to the bindings in the following direction are activated:

- `input1 -> a`
- `a -> b`

When `input2` is changed, the contexts corresponding to the bindings in the following direction are activated:

- `input2 -> b`
- `b -> a`

Explicit Contexts

The context of a binding can be set explicitly to a named context, using the `@` operator from the `core` module.

```
a -> b @ context-id
```

The binding `a -> b` is established in the context, of `b`, with identifier `context-id`.

When multiple bindings are established to the same explicit context, the observer node takes on the value of the first operand which does not evaluate to a failure. The operands are ordered by the order in which the explicit bindings are declared in the source file. If all the operands evaluate to failures, the node evaluates to the failure value of the last operand.

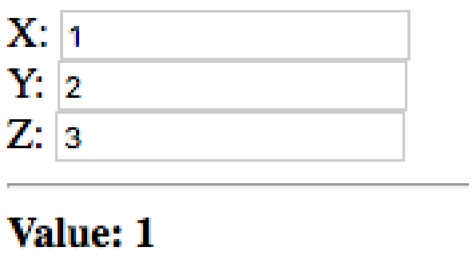
This is better explained with an example application:

ui.html

```
<?
 /import(core)

 x -> node @ context
 y -> node @ context
 z -> node @ context
?>
<!doctype html>
<html>
    <head>
        <title>Explicit Contexts</title>
    </head>
    <body>
      <div><label>X: <input value="<?@ to-int(x) ?>"/></label></div>
      <div><label>Y: <input value="<?@ to-int(y) ?>"/></label></div>
      <div><label>Z: <input value="<?@ to-int(z) ?>"/></label></div>
      <hr/>
      <div><strong>Value: <?@ node ?></strong></div>
    </body>
</html>
```

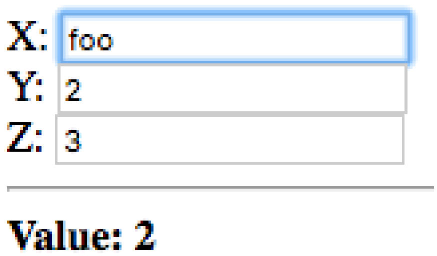
This application is similar to the previous application except the bindings from nodes `x`, `y` and `z`, to `node` are established in an explicit context with identifier `context`. Additionally the input fields are bound to `to-int` instances, of `x`, `y` and `z` which results in `x`, `y` and `z` being bound to the values entered in the fields converted to integers. If a non-integer value is entered in a field, the corresponding node is bound to a failure value.

Let's try it out. Enter some integer values in each of the fields:



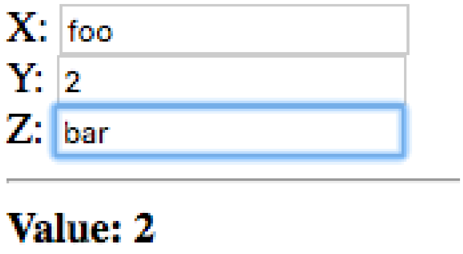
The value entered in the first field, *X*, was displayed. Since a valid integer was entered, node `x` evaluates to the integer value 1. The binding `x -> node` was established first, as the declaration occurs first in the source file, and since `x` does not evaluate to a failure, `node` takes on the value of `x`. The values of `y` and `z` are ignored.

Now let's change `x` to a non-integer value:



The value entered in the second field, 2, is displayed. Since a non-integer value was entered in the first field, `x` evaluates to a failure. `node` thus takes on the value of the next dependency, bound to the explicit context, which does not evaluate to a failure. The dependency is `y` which evaluates to the integer entered in the second field, 2.

Let's see what happens if we enter a non-integer value in the third field:



The displayed value is unchanged since the second dependency, node `y`, already evaluates to a value which is not a failure value. The value of the third dependency `z`, corresponding to the value entered in the third field, is ignored, regardless of whether it evaluates to a failure or not.

Handling Failures with Explicit Contexts

Explicit contexts are a useful tool for handling failures. In the previous application a failure originating from the first input field, was handled by taking the value of the node bound to the second field. Similarly a failure originating from the second input field is handled by taking the value entered in the third field.

The `@` operator also allows a binding to be activated only if the result of the previous binding(s), in the same context, is a failure value with a given type. When the context identifier is of the form `when(context, type)` the binding is only activated if the result of the previous binding(s) is a failure of type `type`.

Example

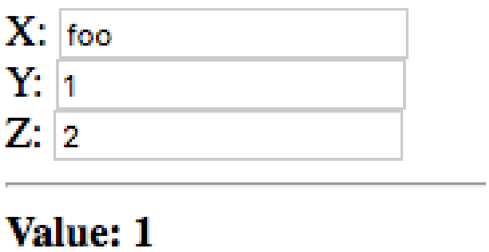
```
x -> node @ context
y -> node @ when(context, Invalid-Integer)
z -> node @ when(context, Negative-Number)
```

Three bindings to `node` are established in the explicit context `context`.

`node` is primarily bound to the value of `x` if it does not evaluate to a failure. If `x` evaluates to a failure of type `Invalid-Integer`, `node` is bound to the value of `y`. If `x`, or `y` evaluate to a failure of type `Negative-Number`, then `node` is bound to the value of `z`.

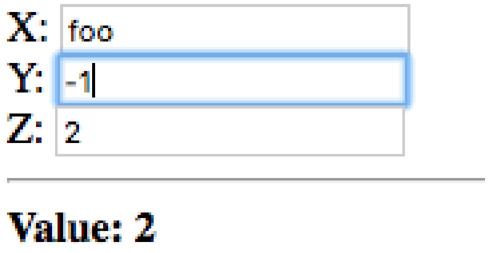
To try this out replace the binding declarations, in the application from the previous section, with the declarations in the example above. Also copy over the definition of the meta-nodes `valid-int`, `validate` and the `Negative-Number` failure type from Section 8.3, into the Tridash code tag. Replace `to-int` with `valid-int` in the inline node declarations within the input field values.

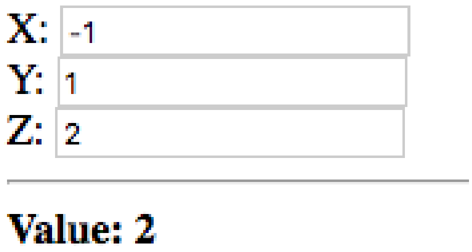
Enter a non-integer value in the first field, and an integer value in the second and third fields:



The value of the second field is displayed, since `node` is bound to it when the value in the first field is not an integer.

Now change the value of the second field to a negative integer, or alternatively enter a negative integer value in the first field:





The value of the third field is displayed in both cases, even when the value of the second field is a valid positive integer. This is due to `node` being bound to the value of the third field when either the value of the first field or second field is a negative number.

Tip

`when` is registered as an infix operator thus the following:

```
a -> b @ when(context, type)
```

can be rewritten as:

```
a -> b @ context when type
```

Improved Error Handling in *Adding Numbers*

Whilst the error handling logic in the *Adding Numbers* application, from Section 8, is adequate and correct, the definition of the `error-message` meta-node, responsible for selecting an appropriate error message, can be improved using explicit contexts. The current definition repeatedly checks whether the failure type of the `value` argument is of a given type using the `fail-type?` meta-node. This is repetitive and does not convey the intent that this is error handling/reporting logic.

The `error-message` meta-node returns:

- The empty string if the `value` argument does not evaluate to a failure.
- The string “Not a valid number!” when `value` evaluates to a failure of type `Invalid-Integer`.
- The string “Number must be greater than or equal to 0!” when `value` evaluates to a failure of type `Negative-Number`.

We can re-implement this logic using bindings to the `self` node with explicit contexts.

The `self` node should primarily be bound to the empty string, if the `value` argument does not evaluate to a failure. There is a handy utility meta-node, `!-`, in the `core` module, which returns the value of its second argument if the first argument does not evaluate to a failure. If the first argument evaluates to a failure value, it is returned. This meta-node is registered as an infix operator thus can be placed between its arguments.

The primary binding can thus be written as follows:

```
value !- "" ->
    self @ context
```

If this binding results in a failure of type `Invalid-Integer`, `self` should be bound to the constant string “Not a valid number!”. This is achieved with the following:

```
"Not a valid number!" ->
    self @ context when Invalid-Integer
```

Finally `self` should be bound to “Number must be greater than or equal to 0!”, if the previous bindings resulted in a failure of type `Negative-Number`.

```
"Number must be greater than or equal to 0!" ->
    self @ context when Negative-Number
```

Putting it all together we have the following definition of `error-message` re-implemented using explicit contexts:

New implementation of error-message

```
error-message(value) : {
    value !- "" ->
        self @ context

    "Not a valid number!" ->
        self @ context when Invalid-Integer

    "Number must be greater than or equal to 0!" ->
        self @ context when Negative-Number
}
```

The advantage of this implementation is that it more explicitly conveys the intent that this is error handling logic. As such it can be optimized more effectively, e.g. if `self` evaluates to a failure of type `Negative-Number`, the check for whether the failure type is `Invalid-Integer` can be skipped altogether.

An additional advantage of this implementation is that the third binding is activated on failures of type `Negative-Number` originating both from the first and second bindings whereas the previous implementation only handled failures originating in `value`. In this case it doesn’t make a difference as the second binding cannot result in a failure of type `Negative-Number`. However this does make a difference, in more complex error handling logic, where the handling of an error may itself result in a new error.

This implementation does, however, have a difference from the previous implementation in that if `value` evaluates to a failure of a type other than `Invalid-Integer` or `Negative-Number` it returns a failure, whereas the previous implementation returned the empty string. In this application it doesn’t make a difference as the arguments passed to `error-message` do not evaluate to failures of other types.

Concise Syntax

Coming up with a context identifier and typing it out repeatedly can become tiresome. The original reason for having an identifier for explicit contexts is to distinguish them from the remaining contexts which are implicitly created and to allow for multiple explicit contexts. However, there is usually only a single explicit context used for handling failures.

To shorten the syntax for binding to an explicit context, a default identifier, such as _ can be given to all explicit contexts which are used only for handling failures. Alternatively, the `@` operator can take a single argument, the node, in which case it is a shorthand for the explicit context with identifier `default`.

```
# The following:
x -> y @ default

# Is equivalent to:
x -> @(y)
```

When the context identifier is of the form `when(type)`, that is omitting the context identifier and leaving only the failure type, the explicit context with identifier `default` is, once again, assumed.

```
# The following:
x -> y @ default when type

# Is equivalent to:
x -> y @ when(type)
```

Node States

So far, we've seen that Tridash is good at producing an output, which is a function of a given input, and ensuring that it is always synchronized with the input. What we haven't seen, however, is mapping a previous output to a new output. In-fact, with the tools introduced so far, this is impossible.

To be able to map a previous output to a new output, a binding has to be established in which the *source* is a function of the *target* node. As an example, to implement a counter, intuitively we might do the following:

```
# This does not work!!!
counter + 1 -> counter
```

The problem here is that a change in the value of `counter` triggers a change in the value of `counter`, which triggers a further change in the value of `counter` *ad infinitum*. What we require is a way to tell Tridash, that when the value of `counter` is updated to `counter + 1`, it should not trigger another update to the value of `counter + 1`. We also need a way to specify when we would like the value of `counter` to be updated to `counter + 1`, as updating it only once is hardly useful.

Stateful Bindings

Node states allow us to control when the value of a node is updated, beyond the simple rule of *whenever the value of one of its dependency nodes changes*. The target of a binding can have an explicit *state* associated with it, using the `::` operator. In this case the binding is referred to as a *stateful binding*.

Explicit state using :: operator

```
a -> b :: state-id
```

The left-hand side of the `::` operator is the node and the right hand side is the state identifier, which is a symbol identifier (similar to a context identifier). The result of this is that the binding `a -> b` only takes effect when `b` ***switches*** to the state with identifier `state-id`. The emphasis is on *switches* as a change in the value of `a` will not automatically trigger a change in the value of `b`. Only a change in the *state* of `b` will trigger a change in its value. This may seem counter-intuitive at first, however if `b` was updated on every change in the value of `a`, and instead of `a` we have `b + 1` we'll end up with the same problem in the previous section.

Important
Stateful bindings declared later in the source take priority over those declared earlier.

A node's state is determined by the value of the special node `/state(node)`. Binding to it allows us to control a node's state.

Example: Counter

```
counter + 1 -> counter :: increment

/state(counter) <-
    case(
        should-increment? : '(increment),
        '(default)
    )
```

Tip

The ' operator returns its argument as a literal symbol. '(id) returns the literal symbol id, whereas id on its own is a reference to the value of the node with identifier id. [a]

---

[a] This performs a similar function to Lisp's quote or ' operator

In this example, a binding counter + 1 -> counter is established which only takes effect when counter switches to the increment state.

The second declaration binds a case expression to the /state(counter) node, thus controlling the state of counter. When should-increment? is true the value of the case expression, and thus the state of counter is increment, otherwise it is default.

The result is that when the value of /state(counter) (the state of counter) is updated to increment, the value of counter is updated to it's previous value incremented by 1.

Interfacing with JavaScript

To provide a runnable example, we have to interface with JavaScript in order to hook into its event system. In the next major release of Tridash, this wont be necessary.

This section will go over only the basics of interfacing with JavaScript, which are necessary for completing this tutorial. A full in-depth tutorial on interfacing with JavaScript, will follow.

Tridash nodes are compiled to runtime node objects, which store the node's value and information about its dependencies, observers, contexts, etc. To be able to reference a runtime node object, from JavaScript, the node has to be given an identifier with which it can be referenced. The public-name attribute, if given, determines the name of this identifier.

Once an identifier is given, it can be accessed as a member of the Tridash.nodes object. Tridash is the object/module storing the Tridash runtime library functions. The nodes member of Tridash is an object storing references to all nodes which have been given a public-name identifier.

Caution

Currently Tridash does not check whether multiple nodes are given the same public-name.

Example: Setting public-name identifier

```
/attribute(node, public-name, "aNode")
```

Example: Referencing the runtime node object in JavaScript

```
var node = Tridash.nodes["aNode"];

// or equivalently if the public-name is a valid JS variable name
var node = Tridash.nodes.aNode;
```

Once a reference is obtained to the runtime node object, the node's value can be set using the set_value method, which takes the value as an argument.

Example: Setting Node Value from JavaScript

```
node.set_value(1);
```

It is important, however, that if set_value will be called on a runtime node object, the node is marked as an *input* node, by setting its input attribute to true.

```
/attribute(node, input, 1)
```

Note
Currently an attribute is set to `true` when it is given the value `1` and set to `false` when it is given the value `0`. In the next release, you'll be able to use the symbols *True* and *False* instead.

Caution
Not every Tridash node corresponds to an actual runtime node object, due to some intermediate nodes being optimized out by the compiler. The only nodes, for which it is guaranteed that a runtime node object is created, are *input* nodes and nodes with no observers, which are assumed to represent *output* nodes.

Example: Counter Application

In this section we'll build a very simple application consisting of a counter which is incremented when a button is pressed.

Let's start off with the Tridash binding declarations. We've in-fact already written the bulk of the code in the previous example, which we can simply copy into our new application.

```
counter + 1 -> counter :: increment

/state(counter) <-
    case(
        should-increment? : '(increment),
        '(default)
    )
```

The node `counter` stores the value of the counter which is incremented when `should-increment?` is true. We'll add the attributes which are necessary in order to be able to set the value of `should-increment?` from JavaScript, namely we need to set a `public-name` identifier and mark it as an `input` node.

```
/attribute(should-increment?, input, 1)
/attribute(should-increment?, public-name, "should_increment")
```

We'll allow the user to set/reset the value of the counter by binding a `start` node to an input field. We'll bind `start` directly to `counter` and give it an initial value of `0`.

```
start -> counter
0 -> start
```

Now let's define the user interface. We need a text input field for entering the initial value for the counter, which will be bound to `start` and an *increment* button. The value of the counter will be displayed below the counter.

ui.html

```
...
<div><label>Start: <input value="<?@ to-int(start) ?>"/></label></div>
<div><button id="increment">Increment</button></div>
<hr/>
<div><strong>Counter: <?@ counter ?></strong></div>
...
```

Note
The HTML boilerplate is not shown.

We've given the *Increment* button the ID `increment` so that we can attach an event listener to its *click* event. We'll do so using the following JavaScript code, in a script tag which should be added below the element where the counter is displayed:

```
<script>
  var increment = document.getElementById('increment');
  var node_increment = Tridash.nodes.should_increment;

  increment.addEventListener('click', function() {
      node_increment.set_value(true);
      node_increment.set_value(false);
  });
</script>
```

The first line obtains a reference to the HTML element with ID `increment`.

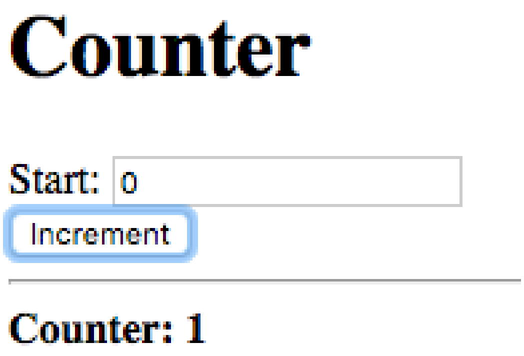
The second line obtains a reference to the `should-increment?` node which was given a `public-name` of `should_increment`.

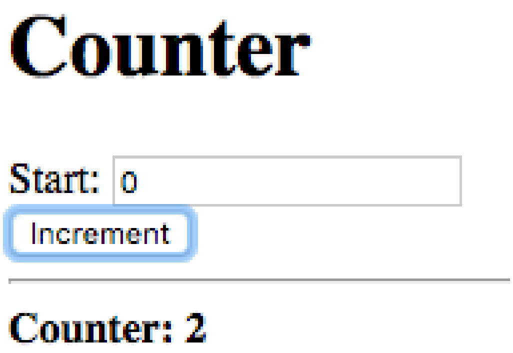
The remainder of the code attaches a listener, for the *click* event, on the *Increment* button. In that listener we first set the value of the `should-increment?` node to true, then immediately afterwards we set it to false again.

Setting the value of `should-increment?` to true, causes the state of `counter` to change to `increment`. Setting it back to false again causes the state to change to `default`.

Note
In a future release, when the HTML library is complete, a subnode `clicked?`, of the element node, will be available which will automatically be set to true when the button is clicked and to false when it is released. Thus the above JavaScript code wont be necessary.

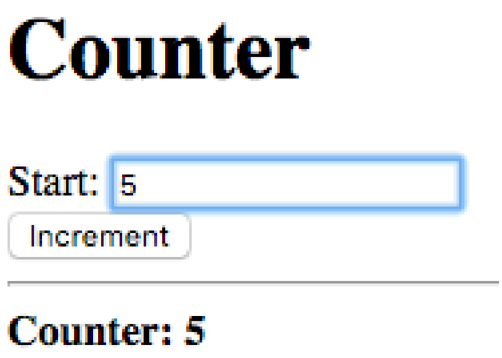
Build and run the application, and press the increment button a few times:

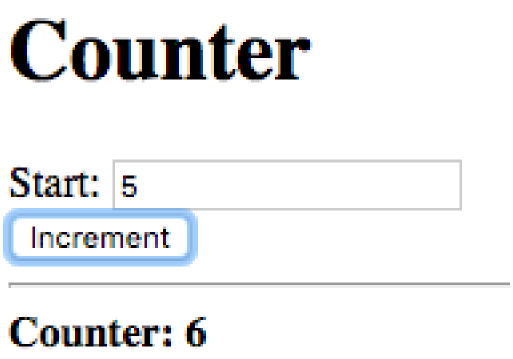




The displayed value, for the counter, is incremented after each press.

Now enter a value in the *Start* field to reset the counter, and then press the increment button again:





The counter is reset to the value entered in the *Start* field. Pressing increment afterwards increments the new counter value.

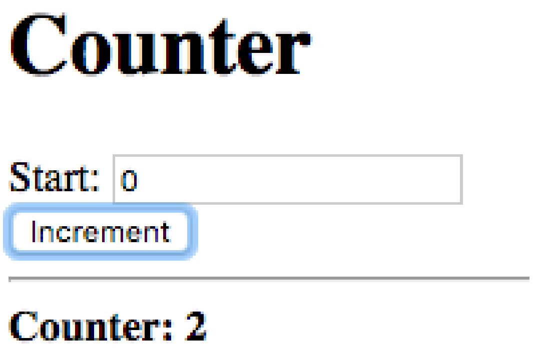
State Transitions

Let's do a little experiment, comment out the line, in the *click* event handler, which sets the value of the *should-increment?* node to *false*, i.e. comment out the following:

```
node_increment.set_value(false);
```

What do you expect to happen? Initially, we might think that since the `should-increment?` node is not being reset to false, the state of `counter` is not being reset to `default`. The state of `counter` will thus switch to `increment` once, after which, there are no further state changes. The result is that the counter will only be incremented the first time the increment button is pressed.

Let's try it. Build and run the application and press the increment button twice.



What happened? The counter carries on incrementing after the first button press. Why?

The declaration:

```
counter + 1 -> counter :: increment
```

states that the binding should only take effect when the state of `counter` switches to the `increment` state. Switching from the `increment` state to the `increment` is still considered as switching to the `increment` state, even though the new state is identical to the previous state. This is due to the fact that each time we're setting the value of the `should-increment?` node to `true`, we're triggering a change in the value of the node `/state(counter)` and thus the state of `counter`, even though the new value of `should-increment?` is identical to its previous value.

The above declaration should thus be thought of as declaring a binding which takes effect whenever `counter` switches from any state, including `increment`, to the `increment` state.

To fix this issue we can specify an explicit *from* state. When specified, the binding only takes effect when the state of the node changes from the *from* state to the *to* state. This is specified using the following syntax:

Node State Binding with Explicit From State

```
a -> b :: previous => next
```

When the state identifier is a functor of the form `previous => next`, `previous` is interpreted as the identifier of the *from* state and *next* is interpreted as the identifier of the *to* state.

To achieve the intuitive behaviour we can limit the binding `counter + 1 -> counter` to only take effect when the state of counter transitions from `default` to `increment`. Replace the binding declaration of `counter` with the following:

```
counter + 1 -> counter :: default => increment
```

This implementation will, however, require two initial button presses before the counter starts incrementing. This is due to the fact that we haven't given `counter` an initial state. The first press causes it to change to `increment`, and then back to default, however since it is not a change from `default` to `increment`, the binding does not take effect. We can fix this by giving `/state(counter)` an initial value of `default`.

Setting Initial State

```
'(default) -> /state(counter)
```

Now the counter starts incrementing after the first press.

Let's repeat the experiment on this new implementation, comment out the line, in the JavaScript script tag, which sets the value of `should-increment?` to `false`. The counter should only increment the first time the *Increment* button is pressed.

This example served to demonstrate the difference between a stateful binding with and without a *from* state. However, in this example, there is no value in specifying a from state, as the previous example, without a from state, was simpler and performed the same function.

Example: Alternating Increment Button

In this example, we'll build a silly application in which the *Increment* button, the button which actually increments the counter, alternates between two buttons. The goal of this example is to demonstrate what can be done with stateful bindings with a *from* state that cannot be done with stateful bindings without a *from* state.

We'll start off with a similar interface to the previous counter application, however with two increment buttons.

ui.html

```
<h1>Counter</h1>
<div><label>Start: <input value="<?@ to-int(start) ?>"/></label></div>
<div>
  <button id="increment1">Increment 1</button>
  <button id="increment2">Increment 2</button>
</div>
<hr/>
<div><strong>Counter: <?@ counter ?></strong></div>
```

Both button's have been given ID's as we'll need to attach event listeners to both buttons, in JavaScript.

We'll need two nodes `clicked1?` and `clicked2?` which change to true when the first and second buttons are clicked, respectively. The values of these nodes will have to be set via JavaScript, thus we'll have to mark them as input nodes and set their `public-name` attributes:

```
/attribute(clicked1?, input, 1)
/attribute(clicked1?, public-name, "clicked1");

/attribute(clicked2?, input, 1)
/attribute(clicked2?, public-name, "clicked2");
```

The following JavaScript code attaches event listeners for the *clicked* events, of both buttons, which simply set the value of the corresponding *clicked?* node to true and them immediately to false, again.

```
var increment1 = document.getElementById('increment1');
var increment2 = document.getElementById('increment2');

var clicked1 = Tridash.nodes.clicked1;
var clicked2 = Tridash.nodes.clicked2;

increment1.addEventListener('click', function() {
    clicked1.set_value(true);
    clicked1.set_value(false);
});

increment2.addEventListener('click', function() {
    clicked2.set_value(true);
    clicked2.set_value(false);
});
```

We'll need two states for the `counter` node:

`increment1`
: Corresponds to the first button being clicked last.

`increment2`
: Corresponds to the second button being clicked last.

The value of `counter` should be incremented only when its state switches from one state to the other, i.e. the button, which was clicked, is different from the previous button to be clicked. This can be achieved using two stateful bindings which take effect during the state transitions `increment1 => increment2`, `increment2 => increment1`.

```
counter + 1 -> counter :: increment1 => increment2
counter + 1 -> counter :: increment2 => increment1
```

Tip

`counter + 1` can be refactored into a separate node to avoid having to type it out twice.

`counter` will retain its previous value during any other state transition.

We need to set `counter`'s state, to `increment1` or `increment2`, based on which button was clicked last. To achieve that we can exploit the fact that each explicit binding to a node, without an explicit context, results in the creation of a new context. When the value of the *source* node, of the binding, changes, the binding context is activated.

We know that the value of `clicked1` changes to true, and then to false, again, when the first button is clicked. The same is true for `clicked2` when the second button is pressed. We want the state of `counter` (`/state(counter)`) to be bound to the literal symbol `increment1`, when the value of `clicked1` changes regardless of what that value is. For that, we can use the utility `!-` meta-node, introduced in Section 9.3, which returns the value of its second argument if its first argument does not evaluate to a failure.

The following are the binding declarations which set the state of `counter`.

```
clicked1? !- '(increment1) -> /state(counter)
clicked2? !- '(increment2) -> /state(counter)
```

Note

The sole purpose of the `!-` operator is to force the value of `/state(counter)` to be updated whenever the value `clicked1` or `clicked2` changes.

To make it obvious which button should be clicked, we'll make the button which increments the counter change to green. We'll bind each button's background color to `"green"` if the other button was the last button to be pressed, and `"gray"` if it was the last button to be pressed. This is achieved with the following:

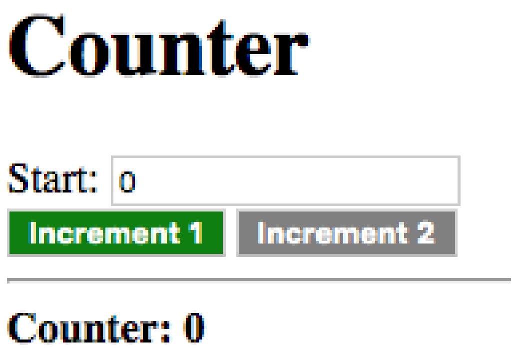
```
increment1 <- /state(counter) = '(increment1)
increment2 <- /state(counter) = '(increment2)

case (increment2 : "green", "gray") ->
    self.increment1.style.backgroundColor
case (increment1 : "green", "gray") ->
    self.increment2.style.backgroundColor
```

Note

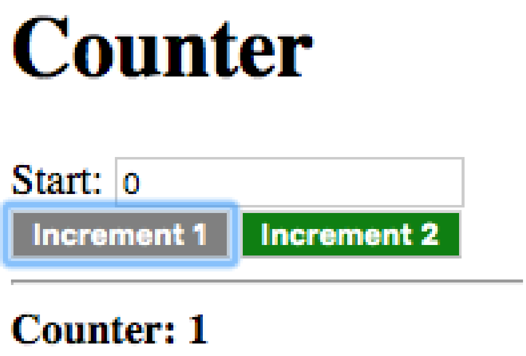
We're comparing the state of counter directly to determine which button was pressed last.

Finally, let's make the initial state of `counter`, `increment2` so that pushing on the first button, increments the counter.

Build and run the application. Initially you should see something similar to the following:

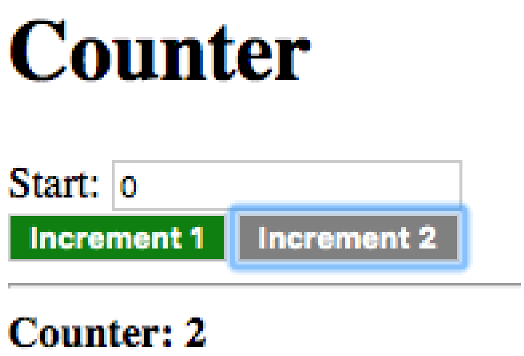


Click on the green *Increment 1* button:



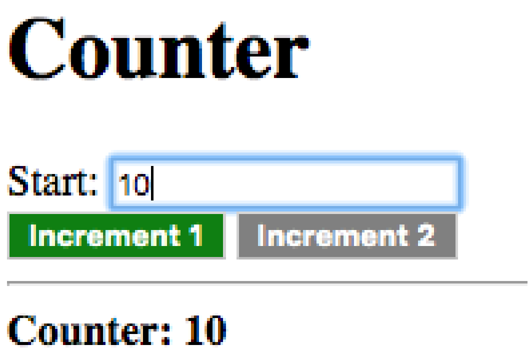
The counter is incremented by one, and the button changes to grey with the other button changing to green. Clicking on the same, now grey, button will not affect the value of the counter.

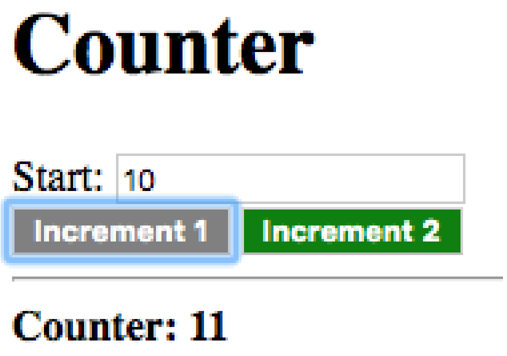
Click on the green *Increment 2* button:



The counter is incremented once again, and button *Increment 1* changes back to green with button *Increment 2* changing back to *grey*.

Just to make sure everything works properly let's reset the counter and push the green button to increment it.





Everything works as expected. The state of `counter` does not affect the binding `start -> counter` as it is a *stateless*, without an explicit state specified, binding.

Exercises

Try out the following as an exercise:

- Change the previous application such that clicking on the grey button, i.e. the button which does not increment the counter, decrements the counter.
- Implement a toggle button of which the background color, and text, changes when pressed.

List Processing

This tutorial is an introduction on processing lists of data. Lists are *conceptually* represented as a linked list of nodes in which the *head* of the node stores the list element and the *tail* stores the next node, i.e. the remainder, of the list. The meta-nodes `head` and `tail`, from the `core` module, return the `head` and `tail` of a list node respectively.

> **Note**
> This is only a conceptual view as not all lists are necessarily implemented as linked lists. Some lists are actually implemented as contiguous arrays which provide a linked list interface. In the current release, only linked lists can be created explicitly, however functionality for creating arrays will be added in a future release.

The empty list is represented by the value of the node `Empty`. The `tail` of the last node in a list is bound to this node.

> **Tip**
> The node `Empty!` is bound to a failure of type `Empty`, which is returned when attempting to access the *head* or *tail* of an empty list.

Creating Lists

The `cons` meta-node creates a list node, taking the value for the `head` and the `tail` as arguments. This can be used to append to the front of an existing list:

```
# Create a list of 1 element, by appending to the front of the empty
# list
l1 <- cons(a, Empty)

# Append to front of l1, creating a list of 2 elements
l2 <- cons(b, l1)
```

The `list` meta-node takes a variable number of arguments and returns a list containing the values of the arguments as elements.

```
# Create list with elements: 1, 2, 3
l <- list(1, 2, 3)
```

The `list*` meta-node, also taking a variable number of arguments, is used to prepend a number of elements to the front of a list. The last argument is interpreted as a list with the remaining arguments prepended to the front of it.

```
# Create list with 1 and 2 prepended to the front of l1
l2 <- list*(1, 2, l1)
```

Higher-Order Meta-Nodes

Meta-Nodes can be passed to other meta-nodes as arguments, or bound to ordinary nodes, in which case the function of the meta-node is referenced.

A node can appear as the operator in a functor node in which case the function, of which the reference is stored in the node's value is applied on the arguments. If the node's value is not a reference to function or the function is applied on an incorrect number of arguments, the result is a failure value.

Example

```
call(f, arg) : f(arg)
func(x) : x

f <- func
result <- call(f, y)
```

In this example the `call` meta-node takes two arguments and returns the result of applying the first argument `f` on the second argument `arg`. The node `f` is bound to a reference to the function of the meta-node `func`, which is then passed to the `call` meta-node.

Outer Node References

An interesting aspect of higher-order programming in Tridash is that when referencing a meta-node as a value, which references the values of nodes declared in the global scope, a binding is established between the referenced nodes and meta-node reference. A binding is also established between the default values of optional arguments, in the case that they are references to other nodes, and the meta-node reference.

Example

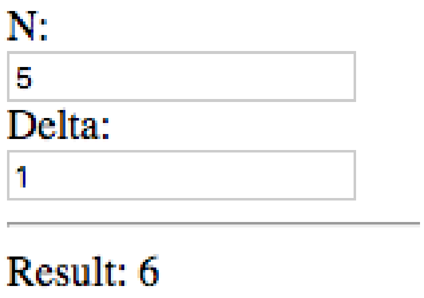
```
# Increment 'x' by the value of the global node 'delta
increment(x) : x + delta

call(f, arg) : f(arg)

result <- call(increment, n)
```

The `increment` meta-node references the value of the global `delta` node. The function of the `increment` meta-node is referenced by the node `call(increment, n)`, thus a binding is established between `delta` and `call(increment, n)`. The result is that whenever the value of `delta` is changed, the value of `call(increment, n)` is updated.

Let's demonstrate this with a simple application. Create a `ui.html` file containing the above code in a Tridash code tag and the following interface in the HTML body.

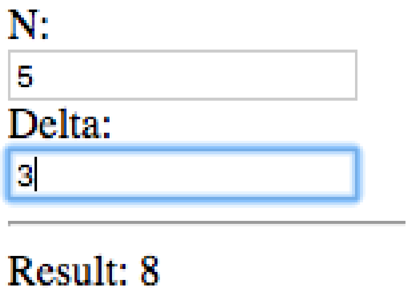
```
<div><label>N:<br/><input value="<?@ to-int(n) ?>"/></label></div>
<div><label>Delta:<br/><input value="<?@ to-int(delta) ?>"/></label></div>
<hr/>
<div>Result: <?@ result ?></div>
```

Build and run the application and enter a value for *N* and *Delta*.



The result of the value entered for *N* plus *Delta* is displayed, nothing new here.

Now change the value for *Delta*:



The result is updated even though there is no direct instance of `increment` but rather a reference to the function of `increment`, which is passed to the `call` meta-node. This demonstrates that an implicit binding `delta -> call(increment, n)` is created due to `increment` referencing the value of `delta` in its definition.

Higher-Order Meta-Nodes in List Processing

Higher-order meta-nodes are extremely useful for processing lists. There are many list processing utility meta-nodes, in the `core` module which take a reference to a meta-node as an argument, and perform an operation on the list using the meta-node. Here are few examples:

map(f, list) The `map` meta-node takes a function `f` and a list as arguments and returns a new list with the result of the applying the function on each element of the list.

Example: map

```
l <- list(1, 2, 3)

1+(n) : n + 1
map(1+, l)     # Result: list(2, 4, 6)
```

The meta-node `1+` returns its argument plus one. `1+` is applied on each element of list `l`, containing the elements 1, 2, 3, using the `map` meta-node. The result is the list containing the elements 2, 4, 6, which is each element of the original list plus one.

foldl(f, list) The `foldl` meta-node reduces a list to a single value by applying a function on the first two elements of the list, and then applies the function again on the result of the previous application and the next element. This is repeated until there are no more elements in the list.

Example: foldl

```
l <- list(1, 2, 3)
foldl(+, l)  # Result ((1 + 2) + 3) = 6
```

In this example the + function is applied on the list containing the elements 1, 2, 3. `foldl` first applies + on the first two elements of the list (1, 2) producing the result 3. The + function is then applied on the result 3 and the next element of the list 3, producing the result 6.

The `foldl'(x, f, list)` function is similar to `foldl` except the function `f` is first applied on `x` and the first element of the list, rather than the first two elements of the list.

The `foldr(f, list)` function is similar to `foldl` except the reduction starts from the last two elements of the list and proceeds backwards until the first element.

Some other useful functions are:

`filter(f, list)`
Returns a list containing only those elements of `list` for which `f` returns true.

`every?(f, list)`
Returns true if `f` returns true for every element of `list`.

`some?(f, list)`
Returns true if `f` returns true for at least one element of `list`.

`not-any?(f, list)`
Returns true if `f` returns false for all elements of `list`.

`not-every?(f, list)`
Returns true if `f` returns false for at least one element of `list`.

Example: Message List

We'll create a simple application consisting of an input field and an *Add Message* button. When the *Add Message* button is pressed, the message entered in the input field is appended to the list of messages, which are displayed below the button.

Start off with the following user interface:

ui.html

```
<div><label>New Message: <input value="<?@ new-message ?>"/></label></div>
<div><button id="add">Add Message</button></div>
<hr/>
<pre><?@ messages ?></pre>
```

The value of the *New Message* input field is bound to the node `new-message`. The value of the `messages` node is bound to the contents of a `pre` tag. This node will store the list of messages in a single formatted string.

The button is given the id `add` so that we can attach an event listener for its click event, in JavaScript:

Add the following code, which is similar to the code seen in Section 10, to a `script` tag below the `pre` tag:

```
var add = document.getElementById('add');
var clicked = Tridash.nodes.clicked;

add.addEventListener('click', function() {
    clicked.set_value(true);
    clicked.set_value(false);
});
```

The value of the node with the public identifier `clicked`, which is the `add-clicked?` node, is set to true and the immediately to false when the button is clicked. Add the following attribute declarations for the `add-clicked?` node:

```
/attribute(add-clicked?, input, 1)
/attribute(add-clicked?, public-name, "clicked")
```

We'll need a node to store the list of messages. Let's call it `message-list` and set its initial value to the empty list.

```
message-list <- Empty
```

The new message entered, bound to `new-message`, has to be added to the end of `message-list`. The `append` meta-node takes two lists and appends the second list at the end of the first list. Thus to append a single item, we'll pass a list of that one item to `append`.

```
append(message-list, list(new-message))
```

We want the value of `new-message` to be appended to `message-list` when the *Add Message* button is clicked. This can be achieved with a stateful binding to `message-list` in the `add-new` state.

```
append(message-list, list(new-message)) ->
    message-list :: add-new
```

The state of `message-list` should be set to `add-new` when the *Add Message* Button is pressed. The `add-clicked?` node is true when the button is being pressed and false otherwise, thus the state of `message-list` can be set with the following `case` expression:

```
case(
    add-clicked? : '(add-new),
    '(default)
) -> /state(message-list)
```

We have completed the functionality for adding a message to the end of the Messages list. All that remains is to format that list into a string which is displayed to the user.

We need a single string containing each message followed by a newline. We'll write a `format-message` meta-node which appends a line break to a message.

Meta-Node format-message

```
format-message(message) :
    format("%s\n", message)
```

`format-message` uses the `format` meta-node, introduced in Section 4, to produce a string containing the message, replacing the `%s` placeholder, followed by a line break.

> **Tip**
> `\n` in a string is an escape sequence for a line break. Other escape sequences are: `\r` — carriage return, `\t` — tab and `\u{<code>}` — Unicode character with code `<code>`.

To format each message, we'll apply `format-message` on each message in `message-list` using `map`.

```
formatted-messages <- map(format-message, message-list)
```

Finally, to concatenate the formatted messages into a single string, we'll use the `string-concat` meta-node, which takes two strings as arguments and returns the concatenation of both strings. We'll need to apply `string-conat` on each element in `formatted-messages` in turn, accumulating the result in a single string. We can do that using the `foldl` node, passing in `string-concat` as the reduction function:

```
messages <- foldl(string-concat, formatted-messages)
```

The resulting string is bound to `messages` which is displayed in the `pre` (preformatted) tag, below the *Add Message* button.

Build and run the application. Enter a message and press the *Add Message* button.

The message is displayed.

Now enter a new message and click the *Add Message* button.

The message is displayed below the old message.

Modules And Organization

Up till this point we haven't given much thought as to how our source code is organized. Instead we've crammed all our code in a Tridash code tag inside a single `ui.html` file. This strategy obviously wont scale for larger applications. Ideally we'd like to have *separation of concerns* with our application divided into multiple source files, each containing the code implementing a separate component of the application. The `ui.html` should ideally contain a minimal amount of Tridash code, limited only to inline node references and, possibly, bindings directly related to the presentation logic. The core application logic should be in a separate source file.

In this tutorial we'll take the *Adding Numbers* application, as it is at the end of Section 9, and reorganize its source code.

Multiple Source Files

The simplest form of code organization is splitting up the application into multiple source files. Source files containing only Tridash code are given the extension `trd`.

Let's extract the validation logic in a separate `validation.trd` file. This includes the meta-nodes `validate`, `valid-int` and the `Negative-Number` failure type.

validation.trd

```
/import(core)

Negative-Number  <- &(Negative-Number)
Negative-Number! <- fail(Negative-Number)

validate(x) :
    case(
        x >= 0 : x,
        Negative-Number!
    )

valid-int(value) : {
    x <- int(value)
    validate(x)
}

/attribute(valid-int, target-node, valid-int)
```

> **Note**
> We've kept the `/import(core)` declaration at the top of the file.

The application logic simply consists of the definition of the `error-message` meta-node, which is responsible for choosing an appropriate error message, the computation of the sum, and the setting of the initial values for `a` and `b`.

Let's place this in a separate source file called `app.trd`

app.trd

```
/import(core)

error-message(value) : {
    value !- "" ->
        @(self)

    "Not a valid number!" ->
        self @ when(Invalid-Integer)
```

```
    "Number must be greater than or equal to 0!" ->
        self @ when(Negative-Number)
}

sum <- a + b

0 -> a
0 -> b
```

> **Note**
> We've kept the `/import(core)` declaration at the top of the file in case we want this file to be processed first by the compiler. If we know this file will be processed after `validation.trd`, which already contains an `/import(core)`, declaration we can omit it.

> **Note**
> We've bound the sum of `a` and `b` to node `sum`, in order to avoid placing application logic in inline node declarations.

All that's left in the `ui.html` file is the user interface elements and the inline bindings to the nodes `a`, `b`, `sum` and the `error-message` instances, which display the error messages.

ui.html

```
<!doctype html>
<html>
    <head>
        <title>Adding Numbers</title>
    </head>
    <body>
      <h1>Adding Numbers</h1>
      <div>
        <label>A: <input id="a" value="<?@ valid-int(a) ?>"/></label>
        <?@ error-message(a) ?>
      </div>
      <div>
        <label>B: <input id="b" value="<?@ valid-int(b) ?>"/></label>
        <?@ error-message(b) ?>
      </div>
      <hr/>
      <div><strong>A + B = <?@ sum ?></strong></div>
    </body>
</html>
```

Building

To build an application consisting of multiple source files, the source files are simply listed, under the `sources` entry, of the build configuration file. Modify the `build.yml` file to the following:

build.yml

```
sources:
  - validation.trd
  - app.trd
  - path: ui.html
    node-name: ui

output:
```

```
  path: app.html
  type: html
  main-ui: ui
```

Note
The source files are processed in the order they are listed.

Since there are no processing options for `validation.trd` and `app.trd`, we've listed the paths to the files directly rather than in the `path` entry of a dictionary.

Tip
To build entirely from the command-line, simply list the files, in the order they are to be processed, after `tridashc`.
The following is equivalent to the build configuration file

```
tridashc validation.trd app.trd path : node-name=ui.html \
    -o path.html -p type=html -p main-ui=ui
```

Modules In Depth

Whilst separating the application into multiple source files, grouping related components in a single file, is a significant cleanup, it would be even better if the nodes could be grouped into different namespace based on their purpose, for example *utility*, *application logic* and *ui*. This would allow us to use only the nodes from the *utility* namespace, without having the rest of the *utility* nodes clash (i.e. have the same identifiers) with the *application logic* nodes. Whilst in this application there are no clashes, keeping the nodes in separate namespaces allows us to use the same `validation.trd` file in another application without the fear that some node is going to clash with other nodes in the application.

Modules are a means of separating nodes into different namespaces, where each module is a namespace in which nodes are contained. A node with identifier `x` in module `mod1` is a distinct node from the node `x` in `mod2`, even though the two nodes share the same identifier.

Note
We've already made use of the `core` module throughout these tutorials.

Creating Modules

Modules are created with the `/module` operator which has the following syntax:

/module Operator Syntax

```
/module(module-name)
```

This indicates that all node references, in the declarations following the `:module` declaration, will occur in the module with identifier `module-name`. Remember that nodes are created the first time they are referenced, thus if a node is referenced which is not in the module, it is created and added to the module.

Example

```
/module(mod1)
x -> node1

/module(mod2)
x -> node2
```

The first reference to the node `x` occurs in module `mod1` thus a node `x` is added to `mod1`. The second referenced occurs in module `mod2` thus the node is added to `mod2`. The two nodes are distinct even though they share the same identifier.

If no module is specified the node references occur in a nameless *init* module. The current module is reset to the *init* module prior to processing each source file.

Important
Module identifiers are distinct from node identifiers, thus a node `mod` will not clash with a module `mod` unless the module is added as a node to the module containing the node `mod`.

Using Modules

This is great but it is of little use if you can't reference a node that is declared in a different module from the current module.

The `/use` operator allows nodes in a module to be referenced as subnodes of a node with same identifier as the module identifier.

/use Operator Syntax

```
/use(mod1)
```

This adds a node `mod1` to the module in which the declaration occurs. Then you can reference a node `x` in `mod1` as a subnode of `mod1`, `mod1.x`. `mod1` is, however, a pseudo-node as its value cannot be referenced nor can bindings involving it be established. It only serves as a means to reference nodes in the module `mod1`.

Tip
To use a meta-node `f` declared in `mod1`, simply reference it as a subnode of `mod1`, `mod1.f(a, b)`.

This greatly increases the functionality of modules however sometimes it may become annoying to have to type out the full name of the module over and over again, for each node. You can try keeping the module names short however then you run the risk of module name collisions. The `/use-as` operator allows you to control the identifier of the pseudo-node, that is created in the current module, with which nodes in the module can be referenced.

/use-as Operator Syntax

```
/use-as(mod1, m)
```

This creates a pseudo-node with identifier `m`, with which nodes in `mod1` can be referenced. Nodes in `mod1` can then be referenced as subnodes of `m`.

Note
Both `/use` and `/use-as` will trigger a compilation error if the pseudo-node identifier already names a node in the current module.

Importing Nodes

Sometimes you would like to explicitly add a node in another module to the current module, so that you don't have to reference it as a subnode of the module. The `/import` operator allows you to do this.

It has two forms:

- A short form taking only the module as an argument, in which case all nodes exported from the module are added to the current module.
- A long form in which the first argument is the module and the following arguments are the individual nodes to import from the module. Only the nodes listed are imported.

Example

```
# Short form: Import all nodes exported from mod1
/import(mod1)

# Long form: Only import nodes x, y, z
/import(mod1, x, y, z)
```

Important
The short form only imports those nodes which are exported from the module not all nodes.

Note
The long form allows you to choose which nodes are imported into the current module. You can list any node in the module, not just an exported node.

`/import` also has a side-effect in that if an imported node, whether imported by the long or short form, is registered as an infix operator, its entry in the operator table is copied over to the operator table of the current module so that it can also be written in infix position in the current module.

Example

```
# @ is a meta-node that is registered as an infix operator
/import(mod1, @)

# It can be also be placed in infix position in the current module
x @ y
```

You cannot place a node in infix position if it is referenced as a subnode of the module.

```
/use(mod1)

# The following will not compile as you cannot place a subnode in
# infix position.

x mod1.@ y

# Instead you have to write it in prefix notation:
mod1.@(x, y)
```

Exporting Nodes

We mentioned that the short form of the `/import` operator imports all nodes which are exported from the module. Nodes are exported from the current module using the `/export` operator.

```
/module(mod1)

# Exports nodes x, y and z from the current module
/export(x, y, z)
```

Importing `mod1` by the short form, `/import(mod1)`, will import nodes `x`, `y` and `z` into the module.

`/export` can take any number of arguments and multiple `/export` declarations will result in the nodes listed in each declaration being exported.

Directly Reference Node in Another Module

The `/in` operator references a node in another module, for which a symbol has not been created in the current module using `/use` or `/use-as`.

/in Operator Syntax

```
/in(module, node)
```

where `module` is the name of the `module`, as declared by the `/module` operator, and `node` is the node expression which is processed in `module`.

This operator is most useful when writing macros, however there is rarely a need for it when writing code directly as whatever can be achieved with `/in` can be achieved in a more readable manner with `/use`, `/use-as` or `/import`.

Adding Modularity to *Adding Numbers*

Let's group the nodes declared in the `validation.trd` file, i.e. the nodes related to the input validation logic into a module called `validation`. To do that simply add the declaration `/module(validation)` to the top of the file.

We mainly require the `valid-int` meta-node and `Negative-Number` failure type node to be referenced outside the `validation` module, thus we'll export those nodes using the declaration `/export(valid-int, Negative-Number)`.

Note

We haven't exported `validate` and `Negative-Number!` as those are only used in the implementation of `valid-int`, and are not used outside the `validation.trd` file.

---

validation.trd

```
/module(validation)
/import(core)
...
/export(valid-int, Negative-Number)
```

We'll group the main application logic into a `sum-app` module, by adding the declaration `/module(sum-app)` to the top of the `app.trd` file. The nodes exported from the `validation` module have to be imported in this module, by adding an import declaration for the module after the import declaration for the `core` module. We'll contain the user interface in this module, thus we wont be needing to export any nodes from it.

app.trd

```
/module(sum-app)

/import(core)
/import(validation)

...
```

Finally, we have to add a Tridash code tag to the top of the `ui.html` file, which changes the module to `sum-app`, since the `sum` and `error-message` nodes are contained in it.

ui.html

```
<? /module(sum-app) ?>
<!doctype html>
<html>
    <head>
        <title>Adding Numbers</title>
    </head>
    <body>
```

```
    <h1>Adding Numbers</h1>
    <div>
      <label>A: <input id="a" value="<?@ valid-int(a) ?>"/></label>
      <?@ error-message(a) ?>
    </div>
    <div>
      <label>B: <input id="b" value="<?@ valid-int(b) ?>"/></label>
      <?@ error-message(b) ?>
    </div>
    <hr/>
    <div><strong>A + B = <?@ sum ?></strong></div>
  </body>
</html>
```

We've successfully divided our source code into multiple modules, based on the purpose of the nodes defined in it. However, the node which references the contents of the `ui.html` file is still added to the *init* module. Whilst in this application it doesn't pose a problem as there is no other node with identifier `ui` in the *init* module, it may become a problem if there is a need to reference HTML elements from within the `app.trd` file. Remember HTML elements can only be referenced as subnodes of `self`, within the HTML file itself. Outside the file they have to be referenced as subnodes of the node which references the contents of the HTML file.

In order for the `ui` node to be created in a module other than *init*, the `node-name` option has to be of the following form `module.name`, where `module` is the module in which the node should be created and `name` is the name of the node. The same syntax applies in the `main-ui` output option.

Change the `build.yml` file to the following:

build.yml

```
sources:
  - util.trd
  - app.trd
  - path: ui.html
    node-name: sum-app.ui

output:
  path: app.html
  type: html
  main-ui: sum-app.ui
```

With this you can now reference HTML elements, from `app.trd`, as subnodes of the `ui` node.

Build and run the application. You wont see any new features however we've significantly improved the organization of the code and thereby improved the maintainability of the application.

Tip

You wouldn't typically divide an application this small into multiple modules, however we've done so here in order to demonstrate how it is done.

Infix Operators

We have referred to some meta-nodes as being *registered as infix operators*. This allows them to be placed in infix position instead of prefix position. It turns out you can do the same for your own nodes. This section describes how.

Precedence and Associativity Basics

Each module has an operator table, which contains the identifiers of all nodes which can be placed in infix position as well as their precedence and associativity. The precedence is a number which controls the priority with which operands are grouped with infix operators, in an expression containing multiple different infix operators. Higher numbers indicate greater precedence.

The multiplication `*` operator has a greater precedence (200), than the addition + operator (100) thus arguments will be grouped with the multiplication operator first and then the addition operator.

The following infix expression:

```
x + y * z
```

is parsed to the following expression in prefix notation:

```
+(x, *(y, z))
```

Notice that the `*` operator is grouped with the operands `y` and `z` first, and then `x` and `*(y, z)` are grouped with the + operator. This is due to `*` having a greater precedence than `+`.

To achieve the following grouping:

```
*(+(x, y), z)
```

enclose `x + y` in parenthesis:

```
(x + y) * z
```

Associativity controls the grouping of operands in an expression containing multiple instances of the same infix operator. The + operator has left associativity.

Thus the following infix expression:

```
x + y + z
```

is parsed to the following expression in prefix notation:

```
+(+(x, y), z)
```

i.e. it is equivalent to

```
(x + y) + z
```

If the + operator were to have right associativity, the expression would be parsed to the following:

```
+(x, +(y, z))
```

Below is a table showing the precedence and associativity of some of the builtin operators.

Operator	Precedence	Associativity
`->`	10	right
`<-`	10	left
`!-`	15	right
`or`	20	left
`and`	25	left
`+`	100	left
`-`	100	left
`*`	200	left
`/`	200	left

Tip
Visit the `modules/core/operators.trd` file of your Tridash installation to see the full list.

Registering your own infix operators

Node identifiers can be registered as infix operators with the special `/operator` declaration.

/operator Syntax

```
/operator(id, precedence, [left | right])
```

The first argument is the identifier, the second argument is the operator precedence as a number and the final argument is the symbol `left` or `right` for left or right associativity. If the third argument is omitted it defaults to `left`.

This declaration adds an infix operator to the operator table of the current module. In the declarations, following the `/operator` declaration, `id` can be placed in infix position.

> **Note**
> `id` can be any valid identifier, not just an identifier consisting only of special symbols. However, as a result, a space is required in between the operator and its operands.

It is not checked whether `id` actually names an existing node, however using it in infix position only makes sense if `id` names a meta-node.

If the node with identifier `id` is imported into another module, its entry in the operator table, of the module from which it is imported, is copied into the operator table of the module into which it is imported.

The precedence and associativity of existing operators can be changed by an `/operator` declaration, however only the operator table of the current module is changed even if the operator is an imported node.

Example: Infix `add` Operator

To demonstrate how you would go about registering a meta-node as an infix operator, we'll write an `add` meta-node which computes the sum of two numbers, register it as an infix operator and replace `a + b` with `a add b` in the *Adding Numbers* Application.

> **Note**
> There is no value in writing a new meta-node which is simply a wrapper over a builtin meta-node and registering it as an infix operator. The purpose of this tutorial is simply to demonstrate how you would register your own meta-node as an infix operator.

We'll first define `add` and then register as an infix operator with precedence 100 and *left* associativity which is the same as the builtin + operator.

Add the following somewhere near the top in `app.trd`:

```
add(a, b) : a + b

/operator(add, 100, left)
```

Now change the binding declaration to `sum` with the following:

```
sum <- a add b
```

That's it you've now added your own infix operator to the language.

What's Next?

You've completed the introductory tutorials which introduce the features of the language. More tutorials will follow shortly, on more advanced topics such as the following:

- Pattern Matching
- String processing
- Writing your own Macros
- Foreign Function Interface
- Controlling Optimizations

Tridash is still in the proof of concept phase, but is slowly advancing to the point where it is fully usable for real-world applications. There are still corner cases which need to be cleaned up, and features, necessary for real world applications, to implement. The next major release will feature the following:

- A complete HTML library allowing for directly hooking into events, from Tridash, and DOM manipulation
- Standard library with more math functions, string manipulation functions and other data structures besides lists.