Pharo 9 by Example

Stéphane Ducasse and Gordana Rakic with Sebastijan Kaplar and Quentin Ducasse

August 2, 2021

Layout and typography based on the `sbabook` LaTeX class by Damien Pollet.

Contents

Illustrations

CHAPTER 1

Morphic

Morphic is the name given to Pharo's graphical interface. Morphic supports two main aspects: on one hand Morphic defines all the low-level graphical entities and related infrastructure (events, drawing,...) and on the other hand Morphic defines all the widgets available in Pharo. Morphic is written in Pharo, so it is fully portable between operating systems. As a consequence, Pharo looks exactly the same on Unix, MacOS and Windows. What distinguishes Morphic from most other user interface toolkits is that it does not have separate modes for *composing* and *running* the interface: all the graphical elements can be assembled and disassembled by the user, at any time. We thank Hilaire Fernandes for permission to base this chapter on his original article in French.

1.1 The history of Morphic

Morphic was developed by John Maloney and Randy Smith for the Self programming language, starting around 1993. Maloney later wrote a new version of Morphic for Squeak, but the basic ideas behind the Self version are still alive and well in Pharo Morphic: *directness* and *liveness*. Directness means that the shapes on the screen are objects that can be examined or changed directly, that is, by clicking on them using a mouse. Liveness means that the user interface is always able to respond to user actions: information on the screen is continuously updated as the world that it describes changes. A simple example of this is that you can detach a menu item and keep it as a button.

Bring up the World Menu and Option-Command-Shift click once on it to bring up its morphic halo, then repeat the operation again on a menu item you want to detach, to bring up that item's halo (see Figure 1-1).

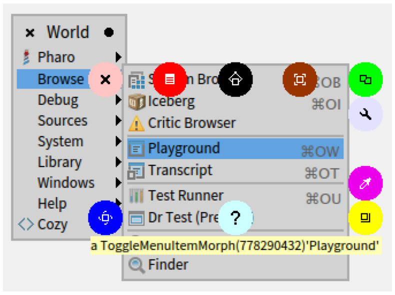


Figure 1-1 Detaching a morph, here the `Playground` menu item, to make it an independent button.

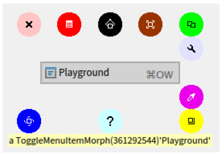


Figure 1-2 Dropping the menu item on the desktop, here the `Playground` menu item is now an independent button.

Now duplicate that item elsewhere on the screen by grabbing the green handle as shown in Figure 1-1.

Once dropped the menu item stays detached from the menu and you can interact with it as if it would be in the menu (see Figure 1-2).

This example illustrates what we mean by *directness* and *liveness*. This gives a lot of power when developing alternate user interface and prototyping alternate interactions.

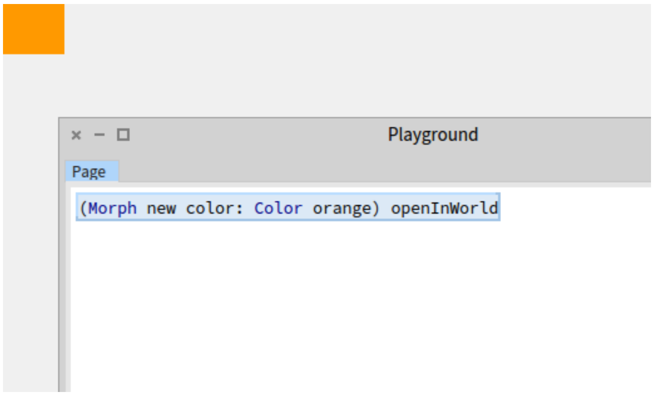
Morphic is a bit showing its age, and the Pharo community is working since several years on a possible replacement. Replacing Morphic means to have both a new low-level infrastructure and a new widget sets. The project is called Bloc and got several iterations. Bloc is about the infrastructure and Brick is a set of widgets built on top. But let us have fun with Morphic.

1.2 Morphs

All of the objects that you see on the screen when you run Pharo are *Morphs*, that is, they are instances of subclasses of class `Morph`. The class `Morph` itself is a large class with many methods; this makes it possible for subclasses to implement interesting behaviour with little code.

Listing 1-3 Creation of a String Morph

```
'Morph' asMorph openInWorld
```



```
(Morph new color: Color orange) openInWorld
```

Figure 1-4 `(Morph new color: Color orange) openInWorld`.

To create a morph to represent a string object, execute the following code in a Playground.

This creates a Morph to represent the string `'Morph'`, and then opens it (that is, displays it) in the *world*, which is the name that Pharo gives to the screen. You should obtain a graphical element (a `Morph`), which you can manipulate by meta-clicking.

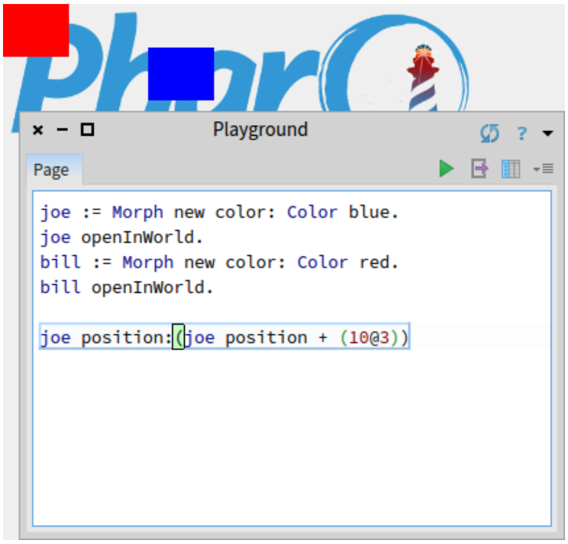
Of course, it is possible to define morphs that are more interesting graphical representations than the one that you have just seen. The method `asMorph` has a default implementation in class `Object` class that just creates a `StringMorph`. So, for example, `Color tan asMorph` returns a StringMorph labeled with the result of `Color tan printString`. Let's change this so that we get a coloured rectangle instead.

Now execute `(Morph new colors: Color orange) openInWorld` in a Playground. Instead of the string-like morph, you get an orange rectangle (see Figure 1-4)! You get the same executing `(Morph new color: Color orange) openInWorld`

1.3 Manipulating morphs

Morphs are objects, so we can manipulate them like any other object in Pharo: by sending messages, we can change their properties, create new subclasses of Morph, and so on.

Every morph, even if it is not currently open on the screen, has a position and a size. For convenience, all morphs are considered to occupy a rectan-



```
joe := Morph new color: Color blue.
joe openInWorld.
bill := Morph new color: Color red.
bill openInWorld.

joe position:(joe position + (10@3))
```

Figure 1-5 Bill and Joe after 10 moves.

gular region of the screen; if they are irregularly shaped, their position and size are those of the smallest rectangular *box* that surrounds them, which is known as the morph's bounding box, or just its *bounds*.

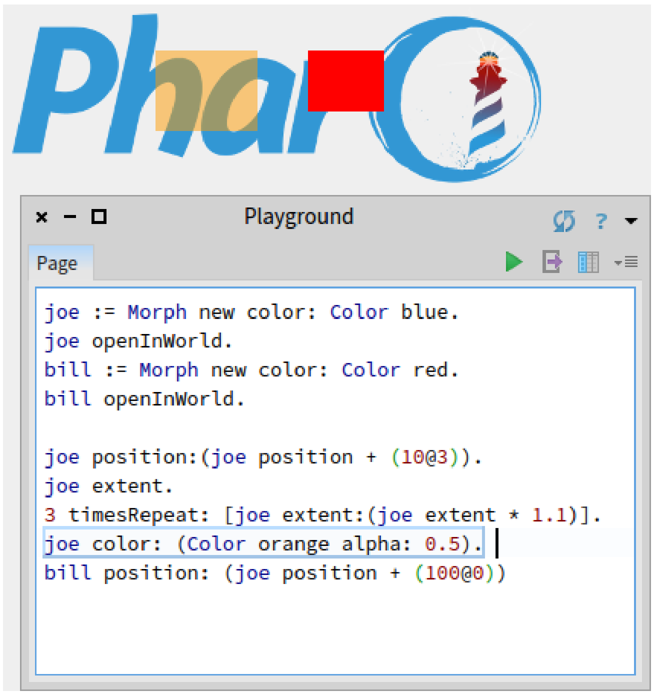
- The `position` method returns a `Point` that describes the location of the morph's upper left corner (or the upper left corner of its bounding box). The origin of the coordinate system is the screen's upper left corner, with *y* coordinates increasing *down* the screen and *x* coordinates increasing to the right.
- The `extent` method also returns a point, but this point specifies the width and height of the morph rather than a location.

Type the following code into a playground and `Do it`:

```
joe := Morph new color: Color blue.
joe openInWorld.
bill := Morph new color: Color red.
bill openInWorld.
```

Then type `joe position` and then `Print it`. To move joe, execute `joe position: (joe position + (10@3))` repeatedly (see Figure 1-5).

It is possible to do a similar thing with size. `joe extent` answers joe's size; to have joe grow, execute `joe extent: (joe extent * 1.1)`. To change the color of a morph, send it the `color:` message with the desired `Color` object as argument, for instance, `joe color: Color orange`. To add transparency, try `joe color: (Color orange alpha: 0.5)`.



```
joe := Morph new color: Color blue.
joe openInWorld.
bill := Morph new color: Color red.
bill openInWorld.

joe position:(joe position + (10@3)).
joe extent.
3 timesRepeat: [joe extent:(joe extent * 1.1)].
joe color: (Color orange alpha: 0.5).
bill position: (joe position + (100@0))
```

Figure 1-6 Bill follows Joe.

To make bill follow joe, you can repeatedly execute this code:

```
bill position: (joe position + (100@0))
```

If you move `joe` using the mouse and then execute this code, bill will move so that it is 100 pixels to the right of `joe`. You can see the result on Figure 1-6. Nothing suprising.

Note that you can delete the morphs you created by

- sending them the message delete
- selecting the cross in halos that you can bring using Meta-Option click.

1.4 Composing morphs

One way of creating new graphical representations is by placing one morph inside another. This is called *composition*; morphs can be composed to any depth. You can place a morph inside another by sending the message `addMorph:` to the container morph.

Try adding a morph to another one as follows:

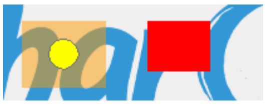


Figure 1-7 The balloon is contained inside joe, the translucent orange morph.

```
balloon := BalloonMorph new color: Color yellow.
joe addMorph: balloon.
balloon position: joe position.
```

The last line positions the balloon at the same coordinates as joe. Notice that the coordinates of the contained morph are still relative to the screen, not to the containing morph. This absolute way of positioning morph is not really good and it makes programming morphs feels a bit odd. But there are many methods available to position a morph; browse the `geometry` protocol of class `Morph` to see for yourself. For example, to center the balloon inside joe, execute `balloon center: joe center`.

If you now try to grab the balloon with the mouse, you will find that you actually grab joe, and the two morphs move together: the balloon is *embedded* inside joe. It is possible to embed more morphs inside joe. In addition to doing this programmatically, you can also embed morphs by direct manipulation.

1.5 Creating and drawing your own morphs

While it is possible to make many interesting and useful graphical representations by composing morphs, sometimes you will need to create something completely different.

To do this you define a subclass of `Morph` and override the `drawOn:` method to change its appearance.

The morphic framework sends the message `drawOn:` to a morph when it needs to redisplay the morph on the screen. The parameter to `drawOn:` is a kind of `Canvas`; the expected behaviour is that the morph will draw itself on that canvas, inside its bounds. Let's use this knowledge to create a cross-shaped morph.

Using the browser, define a new class `CrossMorph` inheriting from `Morph`:

```
Morph subclass: #CrossMorph
  instanceVariableNames: ''
  classVariableNames: ''
  package: 'PBE-Morphic'
```

We can define the `drawOn:` method like this:

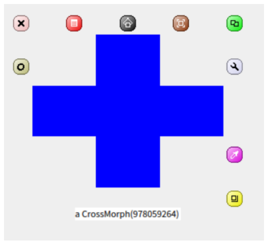


Figure 1-8 A CrossMorph with its halo; you can resize it as you wish.

```
CrossMorph >> drawOn: aCanvas
  | crossHeight crossWidth horizontalBar verticalBar |
  crossHeight := self height / 3.
  crossWidth := self width / 3.
  horizontalBar := self bounds insetBy: 0 @ crossHeight.
  verticalBar := self bounds insetBy: crossWidth @ 0.
  aCanvas fillRectangle: horizontalBar color: self color.
  aCanvas fillRectangle: verticalBar color: self color
```

Sending the bounds message to a morph answers its bounding box, which is an instance of Rectangle. Rectangles understand many messages that create other rectangles of related geometry. Here, we use the insetBy: message with a point as its argument to create first a rectangle with reduced height, and then another rectangle with reduced width.

To test your new morph, execute CrossMorph new openInWorld.

The result should look something like Figure 1-8. However, you will notice that the sensitive zone — where you can click to grab the morph — is still the whole bounding box. Let’s fix this.

When the Morphic framework needs to find out which Morphs lie under the cursor, it sends the message containsPoint: to all the morphs whose bounding boxes lie under the mouse pointer. So, to limit the sensitive zone of the morph to the cross shape, we need to override the containsPoint: method.

Define the following method in class CrossMorph:

```
CrossMorph >> containsPoint: aPoint
  | crossHeight crossWidth horizontalBar verticalBar |
  crossHeight := self height / 3.
  crossWidth := self width / 3.
  horizontalBar := self bounds insetBy: 0 @ crossHeight.
  verticalBar := self bounds insetBy: crossWidth @ 0.
  ^ (horizontalBar containsPoint: aPoint) or: [ verticalBar
    containsPoint: aPoint ]
```

This method uses the same logic as drawOn:, so we can be confident that the points for which `containsPoint:` answers `true` are the same ones that will be colored in by `drawOn:`. Notice how we leverage the `containsPoint:` method in class `Rectangle` to do the hard work.

There are two problems with the code in the two methods above.

The most obvious is that we have duplicated code. This is a cardinal error: if we find that we need to change the way that `horizontalBar` or `verticalBar` are calculated, we are quite likely to forget to change one of the two occurrences. The solution is to factor out these calculations into two new methods, which we put in the `private` protocol:

```
CrossMorph >> horizontalBar
  | crossHeight |
  crossHeight := self height / 3.
  ^ self bounds insetBy: 0 @ crossHeight
```

```
CrossMorph >> verticalBar
  | crossWidth |
  crossWidth := self width / 3.
  ^ self bounds insetBy: crossWidth @ 0
```

We can then define both `drawOn:` and `containsPoint:` using these methods:

```
CrossMorph >> drawOn: aCanvas
  aCanvas fillRectangle: self horizontalBar color: self color.
  aCanvas fillRectangle: self verticalBar color: self color
```

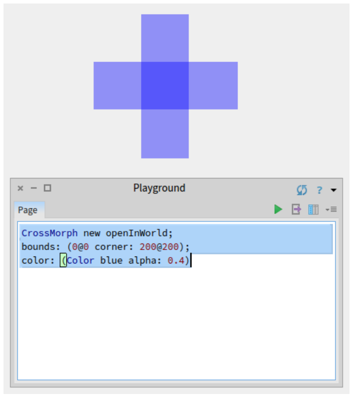
```
CrossMorph >> containsPoint: aPoint
  ^ (self horizontalBar containsPoint: aPoint) or: [ self
    verticalBar containsPoint: aPoint ]
```

This code is much simpler to understand, largely because we have given meaningful names to the private methods. In fact, it is so simple that you may have noticed the second problem: the area in the center of the cross, which is under both the horizontal and the vertical bars, is drawn twice. This doesn't matter when we fill the cross with an opaque colour, but the bug becomes apparent immediately if we draw a semi-transparent cross, as shown in Figure 1-9.

Execute the following code in a playground:

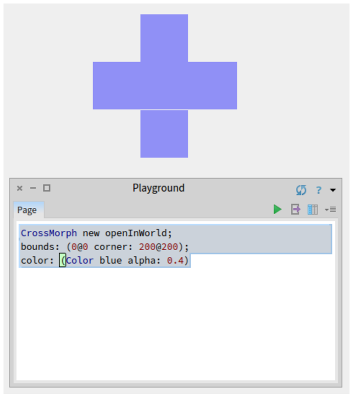
```
CrossMorph new openInWorld;
   bounds: (0@0 corner: 200@200);
   color: (Color blue alpha: 0.4)
```

The fix is to divide the vertical bar into three pieces, and to fill only the top and bottom. Once again we find a method in class `Rectangle` that does the hard work for us: `r1 areasOutside: r2` answers an array of rectangles comprising the parts of `r1` outside `r2`. Here is the revised code:



```
CrossMorph new openInWorld;
bounds: (0@0 corner: 200@200);
color: (Color blue alpha: 0.4)
```

Figure 1-9 The center of the cross is filled twice with the color.



```
CrossMorph new openInWorld;
bounds: (0@0 corner: 200@200);
color: (Color blue alpha: 0.4)
```

Figure 1-10 The cross-shaped morph, showing a row of unfilled pixels.

```
CrossMorph >> drawOn: aCanvas
  | topAndBottom |
  aCanvas fillRectangle: self horizontalBar color: self color.
  topAndBottom := self verticalBar areasOutside: self horizontalBar.
  topAndBottom do: [ :each | aCanvas fillRectangle: each color: self
    color ]
```

This code seems to work, but if you try it on some crosses and resize them, you may notice that at some sizes, a one-pixel wide line separates the bottom of the cross from the remainder, as shown in Figure 1-10. This is due to rounding: when the size of the rectangle to be filled is not an integer, `fillRectangle: color:` seems to round inconsistently, leaving one row of pixels unfilled.

We can work around this by rounding explicitly when we calculate the sizes of the bars as shown hereafter:

```
CrossMorph >> horizontalBar
  | crossHeight |
  crossHeight := (self height / 3) rounded.
  ^ self bounds insetBy: 0 @ crossHeight
```

```
CrossMorph >> verticalBar
  | crossWidth |
  crossWidth := (self width / 3) rounded.
  ^ self bounds insetBy: crossWidth @ 0
```

1.6 Mouse events for interaction

To build live user interfaces using morphs, we need to be able to interact with them using the mouse and keyboard. Moreover, the morphs need to be able respond to user input by changing their appearance and position — that is, by animating themselves.

When a mouse button is pressed, Morphic sends each morph under the mouse pointer the message `handlesMouseDown:`. If a morph answers `true`, then Morphic immediately sends it the `mouseDown:` message; it also sends the `mouseUp:` message when the user releases the mouse button. If all morphs answer `false`, then Morphic initiates a drag-and-drop operation. As we will discuss below, the `mouseDown:` and `mouseUp:` messages are sent with an argument — a `MouseEvent` object — that encodes the details of the mouse action.

Let's extend `CrossMorph` to handle mouse events. We start by ensuring that all crossMorphs answer `true` to the `handlesMouseDown:` message. Add the method to `CrossMorph` defined as follows:

```
CrossMorph >> handlesMouseDown: anEvent
  ^ true
```

Suppose that when we click on the cross, we want to change the color of the cross to red, and when we action-click on it, we want to change the color to yellow. We define the `mouseDown:` method as follows:

```
CrossMorph >> mouseDown: anEvent
  anEvent redButtonPressed
    ifTrue: [ self color: Color red ].  "click"
  anEvent yellowButtonPressed
    ifTrue: [ self color: Color yellow ]. "action-click"
  self changed
```

Notice that in addition to changing the color of the morph, this method also sends `self changed`. This makes sure that morphic sends `drawOn:` in a timely fashion.

Note also that once the morph handles mouse events, you can no longer grab it with the mouse and move it. Instead you have to use the halo: Option-Command-Shift click on the morph to make the halo appear and grab either the brown move handle or the black pickup handle at the top of the morph.

The `anEvent` argument of `mouseDown:` is an instance of `MouseEvent`, which is a subclass of `MorphicEvent`. `MouseEvent` defines the `redButtonPressed` and `yellowButtonPressed` methods. Browse this class to see what other methods it provides to interrogate the mouse event.

1.7 Keyboard events

To catch keyboard events, we need to take three steps.

1. Give the *keyboard focus* to a specific morph. For instance, we can give focus to our morph when the mouse is over it.
2. Handle the keyboard event itself with the `handleKeystroke:` method. This message is sent to the morph that has keyboard focus when the user presses a key.
3. Release the keyboard focus when the mouse is no longer over our morph.

Let's extend `CrossMorph` so that it reacts to keystrokes. First, we need to arrange to be notified when the mouse is over the morph. This will happen if our morph answers `true` to the `handlesMouseOver:` message.

```
CrossMorph >> handlesMouseOver: anEvent
  ^ true
```

This message is the equivalent of `handlesMouseDown:` for the mouse position. When the mouse pointer enters or leaves the morph, the `mouseEnter:` and `mouseLeave:` messages are sent to it.

Define two methods so that `CrossMorph` catches and releases the keyboard focus, and a third method to actually handle the keystrokes.

```
CrossMorph >> mouseEnter: anEvent
  anEvent hand newKeyboardFocus: self
```

```
CrossMorph >> mouseLeave: anEvent
  anEvent hand newKeyboardFocus: nil
```

```
CrossMorph >> handleKeystroke: anEvent
  | keyValue |
  keyValue := anEvent keyValue.
  keyValue = 30  "up arrow"
    ifTrue: [self position: self position - (0 @ 1)].
  keyValue = 31  "down arrow"
    ifTrue: [self position: self position + (0 @ 1)].
  keyValue = 29  "right arrow"
    ifTrue: [self position: self position + (1 @ 0)].
  keyValue = 28  "left arrow"
    ifTrue: [self position: self position - (1 @ 0)]
```

We have written this method so that you can move the morph using the arrow keys. Note that when the mouse is no longer over the morph, the `handleKeystroke:` message is not sent, so the morph stops responding to keyboard commands. To discover the key values, you can open a Transcript window and add `Transcript show: anEvent keyValue` to the `handleKeystroke:` method.

The `anEvent` argument of `handleKeystroke:` is an instance of `KeyboardEvent`, another subclass of `MorphicEvent`. Browse this class to learn more about keyboard events.

1.8 Morphic animations

Morphic provides a simple animation system with two main methods: `step` is sent to a morph at regular intervals of time, while `stepTime` specifies the time in milliseconds between `steps`. `stepTime` is actually the *minimum* time between `steps`. If you ask for a `stepTime` of 1 ms, don't be surprised if Pharo is too busy to step your morph that often. In addition, `startStepping` turns on the stepping mechanism, while `stopStepping` turns it off again. `isStepping` can be used to find out whether a morph is currently being stepped.

Make `CrossMorph` blink by defining these methods as follows:

```
CrossMorph >> stepTime
  ^ 100
```

```
CrossMorph >> step
  (self color diff: Color black) < 0.1
    ifTrue: [ self color: Color red ]
    ifFalse: [ self color: self color darker ]
```

To start things off, you can open an inspector on a `CrossMorph` using the debug handle which look like a wrench in the morphic halo, type `self startStepping` in the small pane at the bottom, and `Do it`.

You can also redefine the `initialize` method as follows:

```
CrossMorph >> initialize
  super initialize.
  self startStepping
```

Alternatively, you can modify the `handleKeystroke:` method so that you can use the + and - keys to start and stop stepping. Add the following code to the `handleKeystroke:` method:

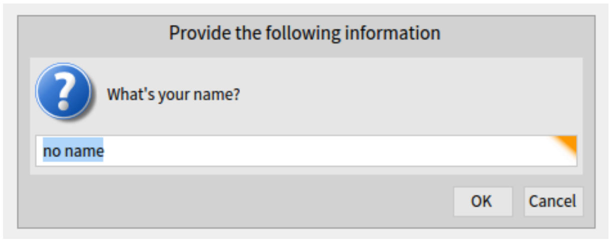


Figure 1-11 An input dialog.

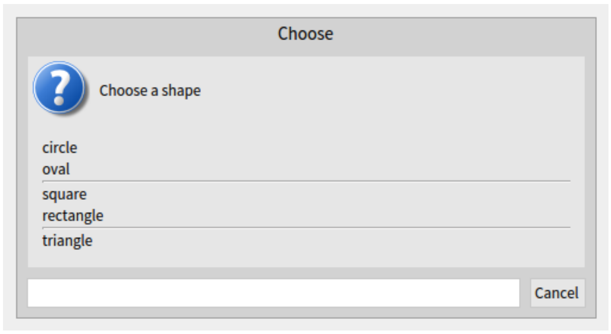


Figure 1-12 Pop-up menu.

```
  keyValue = $+ asciiValue
    ifTrue: [ self startStepping ].
  keyValue = $- asciiValue
    ifTrue: [ self stopStepping ]
```

1.9 Interactors

To prompt the user for input, the `UIManager` class provides a large number of ready to use dialog boxes. For instance, the `request:initialAnswer:` method returns the string entered by the user (Figure 1-11).

```
UIManager default
  request: 'What''s your name?'
  initialAnswer: 'no name'
```

To display a popup menu, use one of the various `chooseFrom:` methods (Figure 1-12):

```
UIManager default
  chooseFrom: #('circle' 'oval' 'square' 'rectangle' 'triangle')
  lines: #(2 4) message: 'Choose a shape'
```

Browse the `UIManager` class and try out some of the interaction methods offered.

1.10 Drag-and-drop

Morphic also supports drag-and-drop. Let's examine a simple example with two morphs, a receiver morph and a dropped morph. The receiver will accept a morph only if the dropped morph matches a given condition: in our example, the morph should be blue. If it is rejected, the dropped morph decides what to do.

Let's first define the receiver morph:

```
Morph subclass: #ReceiverMorph
  instanceVariableNames: ''
  classVariableNames: ''
  package: 'PBE-Morphic'
```

Now define the initialization method in the usual way:

```
ReceiverMorph >> initialize
  super initialize.
  color := Color red.
  bounds := 0 @ 0 extent: 200 @ 200
```

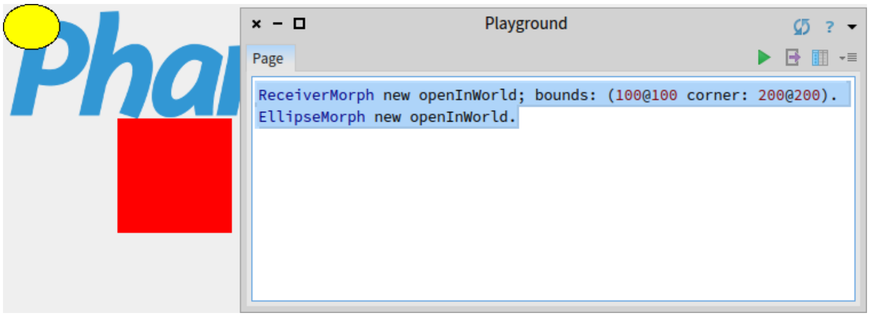
How do we decide if the receiver morph will accept or reject the dropped morph? In general, both of the morphs will have to agree to the interaction. The receiver does this by responding to `wantsDroppedMorph:event:`. Its first argument is the dropped morph, and the second the mouse event, so that the receiver can, for example, see if any modifier keys were held down at the time of the drop. The dropped morph is also given the opportunity to check and see if it likes the morph onto which it is being dropped, by responding to the message `wantsToBeDroppedInto:`. The default implementation of this method (in class `Morph`) answers `true`.

```
ReceiverMorph >> wantsDroppedMorph: aMorph event: anEvent
  ^ aMorph color = Color blue
```

What happens to the dropped morph if the receiving morph doesn't want it? The default behaviour is for it to do nothing, that is, to sit on top of the receiving morph, but without interacting with it. A more intuitive behavior is for the dropped morph to go back to its original position. This can be achieved by the receiver answering `true` to the message `repelsMorph:event:` when it doesn't want the dropped morph:

```
ReceiverMorph >> repelsMorph: aMorph event: anEvent
  ^ (self wantsDroppedMorph: aMorph event: anEvent) not
```

That's all we need as far as the receiver is concerned.



```
ReceiverMorph new openInWorld; bounds: (100@100 corner: 200@200).
EllipseMorph new openInWorld.
```

Figure 1-13 A `ReceiverMorph` and an `EllipseMorph`.

Create instances of `ReceiverMorph` and `EllipseMorph` in a playground:

```
ReceiverMorph new openInWorld;
    bounds: (100@100 corner: 200@200).
EllipseMorph new openInWorld.
```

Try to drag and drop the yellow `EllipseMorph` onto the receiver. It will be rejected and sent back to its initial position.

To change this behaviour, change the color of the ellipse morph to the color blue (by sending it the message `color: Color blue;` right after `new`). Blue morphs should be accepted by the `ReceiverMorph`.

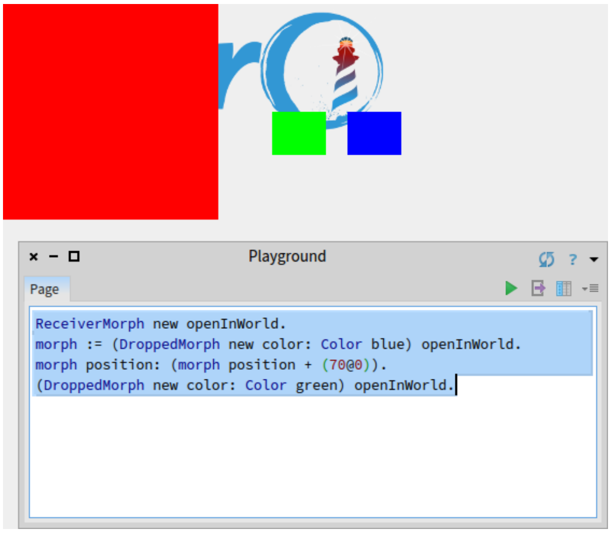
Let's create a specific subclass of `Morph`, named `DroppedMorph`, so we can experiment a bit more. Let us define a new kind of morph called `DroppedMorph`.

```
Morph subclass: #DroppedMorph
  instanceVariableNames: ''
  classVariableNames: ''
  package: 'PBE-Morphic'
```

```
DroppedMorph >> initialize
  super initialize.
  color := Color blue.
  self position: 250 @ 100
```

Now we can specify what the dropped morph should do when it is rejected by the receiver; here it will stay attached to the mouse pointer:

```
DroppedMorph >> rejectDropMorphEvent: anEvent
  | h |
  h := anEvent hand.
  WorldState addDeferredUIMessage: [ h grabMorph: self ].
  anEvent wasHandled: true
```



```
ReceiverMorph new openInWorld.
morph := (DroppedMorph new color: Color blue) openInWorld.
morph position: (morph position + (70@0)).
(DroppedMorph new color: Color green) openInWorld.
```

Figure 1-14 Creation of DroppedMorph and ReceiverMorph.

Sending the hand message to an event answers the *hand*, an instance of HandMorph that represents the mouse pointer and whatever it holds. Here we tell the World that the hand should grab self, the rejected morph.

Create two instances of DroppedMorph of different colors, and then drag and drop them onto the receiver.

```
ReceiverMorph new openInWorld.
morph := (DroppedMorph new color: Color blue) openInWorld.
morph position: (morph position + (70@0)).
(DroppedMorph new color: Color green) openInWorld.
```

The green morph is rejected and therefore stays attached to the mouse pointer.

1.11 A complete example

Let's design a morph to roll a die. Clicking on it will display the values of all sides of the die in a quick loop, and another click will stop the animation.

Define the die as a subclass of BorderedMorph instead of Morph, because we will make use of the border.

```
BorderedMorph subclass: #DieMorph
  instanceVariableNames: 'faces dieValue isStopped'
  classVariableNames: ''
  package: 'PBE-Morphic'
```

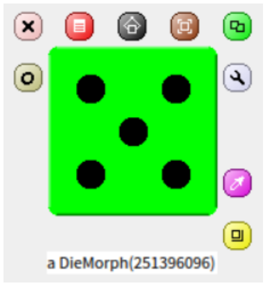


Figure 1-15 The die in Morphic.

The instance variable `faces` records the number of faces on the die; we allow dice with up to 9 faces! `dieValue` records the value of the face that is currently displayed, and `isStopped` is true if the die animation has stopped running. To create a die instance, we define the `faces: n` method on the *class* side of `DieMorph` to create a new die with `n` faces.

```
DieMorph class >> faces: aNumber
  ^ self new faces: aNumber
```

The `initialize` method is defined on the instance side in the usual way; remember that `new` automatically sends `initialize` to the newly-created instance.

```
DieMorph >> initialize
  super initialize.
  self extent: 50 @ 50.
  self
    useGradientFill;
    borderWidth: 2;
    useRoundedCorners.
  self setBorderStyle: #complexRaised.
  self fillStyle direction: self extent.
  self color: Color green.
  dieValue := 1.
  faces := 6.
  isStopped := false
```

We use a few methods of `BorderedMorph` to give a nice appearance to the die: a thick border with a raised effect, rounded corners, and a color gradient on the visible face. We define the instance method `faces:` to check for a valid parameter as follows:

```
DieMorph >> faces: aNumber
  "Set the number of faces"

  ((aNumber isInteger and: [ aNumber > 0 ]) and: [ aNumber <= 9 ])
    ifTrue: [ faces := aNumber ]
```

It may be good to review the order in which the messages are sent when a die is created. For instance, if we start by evaluating `DieMorph faces: 9`:

- The class method `DieMorph class >> faces:` sends `new` to `DieMorph class`.
- The method for `new` (inherited by `DieMorph class` from `Behavior`) creates the new instance and sends it the `initialize` message.
- The `initialize` method in `DieMorph` sets `faces` to an initial value of 6.
- `DieMorph class >> new` returns to the class method `DieMorph class >> faces:`, which then sends the message `faces: 9` to the new instance.
- The instance method `DieMorph >> faces:` now executes, setting the `faces` instance variable to 9.

Before defining `drawOn:`, we need a few methods to place the dots on the displayed face:

```
DieMorph >> face1
  ^ {(0.5 @ 0.5)}
```

```
DieMorph >> face2
  ^{0.25@0.25 . 0.75@0.75}
```

```
DieMorph >> face3
  ^{0.25@0.25 . 0.75@0.75 . 0.5@0.5}
```

```
DieMorph >> face4
  ^{0.25@0.25 . 0.75@0.25 . 0.75@0.75 . 0.25@0.75}
```

```
DieMorph >> face5
  ^{0.25@0.25 . 0.75@0.25 . 0.75@0.75 . 0.25@0.75 . 0.5@0.5}
```

```
DieMorph >> face6
  ^{0.25@0.25 . 0.75@0.25 . 0.75@0.75 . 0.25@0.75 . 0.25@0.5 .
    0.75@0.5}
```

```
DieMorph >> face7
  ^{0.25@0.25 . 0.75@0.25 . 0.75@0.75 . 0.25@0.75 . 0.25@0.5 .
    0.75@0.5 . 0.5@0.5}
```

```
DieMorph >> face8
  ^{0.25@0.25 . 0.75@0.25 . 0.75@0.75 . 0.25@0.75 . 0.25@0.5 .
    0.75@0.5 . 0.5@0.5 . 0.5@0.25}
```

```
DieMorph >> face9
  ^{0.25@0.25 . 0.75@0.25 . 0.75@0.75 . 0.25@0.75 . 0.25@0.5 .
    0.75@0.5 . 0.5@0.5 . 0.5@0.25 . 0.5@0.75}
```

These methods define collections of the coordinates of dots for each face. The coordinates are in a square of size 1x1; we will simply need to scale them to place the actual dots.

Listing 1-16 Create a Die 6

```
(DieMorph faces: 6) openInWorld.
```

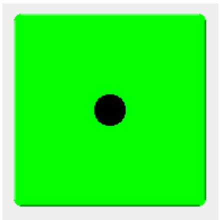


Figure 1-17 A new die 6 with `(DieMorph faces: 6) openInWorld`

The `drawOn:` method does two things: it draws the die background with the `super`-send, and then draws the dots as follows:

```
DieMorph >> drawOn: aCanvas
  super drawOn: aCanvas.
  (self perform: ('face', dieValue asString) asSymbol)
    do: [ :aPoint | self drawDotOn: aCanvas at: aPoint ]
```

The second part of this method uses the reflective capacities of Pharo. Drawing the dots of a face is a simple matter of iterating over the collection given by the `faceX` method for that face, sending the `drawDotOn:at:` message for each coordinate. To call the correct `faceX` method, we use the `perform:` method which sends a message built from a string, `('face', dieValue asString) asSymbol`.

```
DieMorph >> drawDotOn: aCanvas at: aPoint
  aCanvas
    fillOval: (Rectangle
      center: self position + (self extent * aPoint)
      extent: self extent / 6)
    color: Color black
```

Since the coordinates are normalized to the `[0:1]` interval, we scale them to the dimensions of our die: `self extent * aPoint`. We can already create a die instance from a playground (see result on Figure 1-17):

To change the displayed face, we create an accessor that we can use as `myDie dieValue: 5`:

```
DieMorph >> dieValue: aNumber
  ((aNumber isInteger and: [ aNumber > 0 ]) and: [ aNumber <= faces
    ])
    ifTrue: [
      dieValue := aNumber.
      self changed ]
```

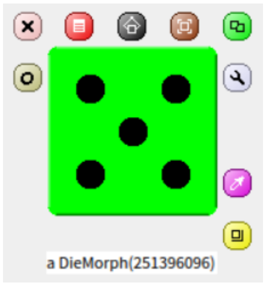


Figure 1-18 Result of `(DieMorph faces: 6) openInWorld; dieValue: 5`.

Now we will use the animation system to show quickly all the faces:

```
DieMorph >> stepTime
  ^ 100
```

```
DieMorph >> step
  isStopped ifFalse: [self dieValue: (1 to: faces) atRandom]
```

Now the die is rolling!

To start or stop the animation by clicking, we will use what we learned previously about mouse events. First, activate the reception of mouse events:

```
DieMorph >> handlesMouseDown: anEvent
  ^ true
```

Second, we will stop and start alternatively a roll on mouse click.

```
DieMorph >> mouseDown: anEvent
  anEvent redButtonPressed
    ifTrue: [isStopped := isStopped not]
```

Now the die will roll or stop rolling when we click on it.

1.12 More about the canvas

The `drawOn:` method has an instance of `Canvas` as its sole argument; the canvas is the area on which the morph draws itself. By using the graphics methods of the canvas you are free to give the appearance you want to a morph. If you browse the inheritance hierarchy of the `Canvas` class, you will see that it has several variants. The default variant of `Canvas` is `FormCanvas`, and you will find the key graphics methods in `Canvas` and `FormCanvas`. These methods can draw points, lines, polygons, rectangles, ellipses, text, and images with rotation and scaling.

It is also possible to use other kinds of canvas, for example to obtain transparent morphs, more graphics methods, antialiasing, and so on. To use these

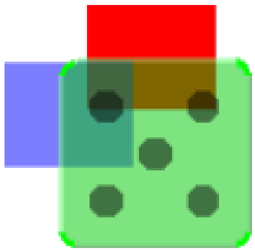


Figure 1-19 The die displayed with alpha-transparency

features you will need an `AlphaBlendingCanvas` or a `BalloonCanvas`. But how can you obtain such a canvas in a `drawOn:` method, when `drawOn:` receives an instance of `FormCanvas` as its argument? Fortunately, you can transform one kind of canvas into another.

To use a canvas with a 0.5 alpha-transparency in `DieMorph`, redefine `drawOn:` like this:

```
DieMorph >> drawOn: aCanvas
  | theCanvas |
  theCanvas := aCanvas asAlphaBlendingCanvas: 0.5.
  super drawOn: theCanvas.
  (self perform: ('face', dieValue asString) asSymbol)
    do: [:aPoint | self drawDotOn: theCanvas at: aPoint]
```

That's all you need to do!

1.13 Chapter summary

Morphic is a graphical framework in which graphical interface elements can be dynamically composed.

- You can convert an object into a morph and display that morph on the screen by sending it the messages `asMorph openInWorld`.
- You can manipulate a morph using Command-Option+Shift click on it and using the handles that appear. (Handles have help balloons that explain what they do.)
- You can compose morphs by embedding one onto another, either by drag and drop or by sending the message `addMorph:`.
- You can subclass an existing morph class and redefine key methods, such as `initialize` and `drawOn:`.
- You can control how a morph reacts to mouse and keyboard events by redefining the methods `handlesMouseDown:`, `handlesMouseOver:`, etc.

- You can animate a morph by defining the methods `step` (what to do) and `stepTime` (the number of milliseconds between steps).

Bibliography