

Slideshow: Functional Presentations

Robert Bruce Findler
University of Chicago
robby@cs.uchicago.edu

Matthew Flatt
University of Utah
mflatt@cs.utah.edu

Abstract

Among slide-presentation systems, the dominant application offers essentially no abstraction capability. Slideshow, an extension of PLT Scheme, represents our effort over the last several years to build an abstraction-friendly slide system. We show how functional programming is well suited to the task of slide creation, we report on the programming abstractions that we have developed for slides, and we describe our solutions to practical problems in rendering slides. We also describe a prototype extension to DrScheme that supports a mixture of programmatic and WYSIWYG slide creation.

Categories and Subject Descriptors

H.4.1 [Information Systems Applications]: Office Automation;
I.7.2 [Document and Text Processing]: Document Preparation

General Terms

Languages

1 Abstraction-Friendly Applications

Strand a computer scientist at an airport, and the poor soul would probably survive for days with only a network-connected computer and five applications: an e-mail client, a web browser, a general-purpose text editor, a typesetting system, and a slide-presentation application. More specifically, while most any mail client or browser would satisfy the stranded scientist, probably only Emacs or vi would do for editing, L^AT_EX for typesetting, and Microsoft PowerPoint™ for preparing slides.

The typical business traveler would more likely insist on Microsoft Word™ for both text editing and typesetting. In part, computer scientists may prefer Emacs and L^AT_EX because text editing has little to do with typesetting, and these different tasks are best handled by different, specialized applications. More importantly, tools such as Emacs, vi, and L^AT_EX are programmable. Through the power

of programming abstractions, a skilled user of these tools becomes even more efficient and effective.

Shockingly, many computer scientists give up the power of abstraction when faced with the task of preparing slides for a talk. PowerPoint is famously easy to learn and use, it produces results that are aesthetically pleasing to most audience members, and it enables users to produce generic slides in minutes. Like most GUI-/WYSIWYG-oriented applications, however, PowerPoint does not lend itself easily to extension and abstraction. PowerPoint provides certain pre-defined abstractions—the background, the default font and color, etc.—but no ability to create new abstractions.

Among those who refuse to work without abstraction, many retreat to a web browser (because HTML is easy to generate programmatically) or the various extension of T_EX (plus a DVI/PostScript/PDF viewer). Usually, the results are not as aesthetically pleasing as PowerPoint slides, and not as finely tuned to the problems of projecting images onto a screen. Moreover, novice users of T_EX-based systems tend to produce slides with far too many words and far too few pictures, due to the text bias of their tool. Meanwhile, as a programming language, T_EX leaves much to be desired.

Slideshow, a part of the PLT Scheme application suite [10], fills the gap left by abstraction-poor slide presentation systems. First and foremost, Slideshow is an embedded DSL for picture generation, but it also provides direct support for step-wise animation, bullet-style text, slide navigation, image scaling (to fit different display and projector types), cross-platform consistency (Windows, Mac OS, and Unix/X), and PostScript output (for ease of distribution). Functional programming naturally supports the definition of picture combinators, and it enables slide creators to create new abstractions that meet their specific needs.

In this paper, we mainly demonstrate how Slideshow as a programming language supports abstraction, but slide creators can also benefit from a measured dose of WYSIWYG slide construction. WYSIWYG tools should be part of the slide language's programming environment, analogous to GUI builders for desktop applications. We therefore report on experimental extensions of the DrScheme programming environment that support interactive slide construction along with language-based abstraction.

Section 2 describes Slideshow's primitives for picture generation, and Section 3 shows how we build on these operations to address common slide-construction tasks. Section 4 briefly addresses practical issues for rendering slides on different media and operating systems. Section 5 describes our prototype extension of DrScheme.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, to republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
ICFP'04, September 19–21, 2004, Snowbird, Utah, USA.
Copyright 2004 ACM 1-58113-905-5/04/0009 ...\$5.00

2 Picture Combinators

A *pict* is the basic building block for pictures in Slideshow. Roughly, a pict consists of a bounding box and a procedure for drawing relative to the box. Ultimately, a slide is represented as a single pict to be drawn on the screen.

As a running example, suppose that we wish to illustrate graph searching to novice programmers, showing how a graph of people is traversed to find the name of a person who lives in a particular city. The illustration will contain boxes labeled with names and locations, directed connections among the boxes, an arrow indicating the starting box, and a cloud that stands in place of many unspecified boxes and connections.

2.1 Pict Basics

To create the basic elements of the graph, we can use `rectangle` and `cloud`. The `rectangle` and `cloud` functions take the height and width of the new pict.

```
(rectangle 20 10)
```



```
(cloud 30 20)
```



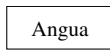
To label the boxes with the names of people, we need `picts` for text. The `text` function takes a string, a font class, and a font size, and it produces a pict for the text.

```
(text "Angua" 'roman 10)
```

Angua

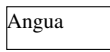
To get a labeled box, we need to combine a text pict with a rectangle pict. The `cc-superimpose` function stacks pictures on top of each other to create a new picture.

```
(cc-superimpose  
  (rectangle 50 20)  
  (text "Angua" 'roman 10))
```



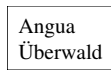
The `cc` part of the name `cc-superimpose` indicates that the `picts` are centered horizontally and vertically as they are stacked. If, instead, we want the label in the top-left of the rectangle, we can use `lt-superimpose`.

```
(lt-superimpose  
  (rectangle 50 20)  
  (text "Angua" 'roman 10))
```



To illustrate distances, our boxes need to contain both a person's name and home. We could put a name in the top-left of a rectangle and the home in the bottom left, but we'd prefer to center both together. The `v1-append` function stacks `picts` vertically, instead of on top of each other.

```
(cc-superimpose  
  (rectangle 50 30)  
  (v1-append  
    (text "Angua" 'roman 10)  
    (text "Überwald" 'roman 10)))
```



The `l` in `v1-append` means that the `picts` are left-aligned as they are stacked. We could right-align the `picts` with `vr-append`, or center them with `vc-append`.

If we want to prefix the boxed fields with "Name:" and "Home:" labels, we can use `hb-append`.

```
(cc-superimpose  
  (rectangle 80 30)  
  (v1-append  
    (hb-append  
      (text "Name: " 'roman 10)  
      (text "Angua" 'roman 10))  
    (hb-append  
      (text "Home: " 'roman 10)  
      (text "Überwald" 'roman 10)))))
```

Name: Angua
Home: Überwald

Naturally, the `b` in `hb-append` means that the `picts` are bottom-aligned as they are stacked horizontally, and `hc-append` and `ht-append` center- and top-align pictures. In addition, `hbl-append` aligns text on baselines, which is useful when `picts` contain text in different fonts or sizes.

```
(cc-superimpose  
  (rectangle 80 30)  
  (v1-append  
    (hbl-append  
      (text "Name: " 'roman 6)  
      (text "Angua" 'roman 10))  
    (hbl-append  
      (text "Home: " 'roman 6)  
      (text "Überwald" 'roman 10)))))
```

Name: Angua
Home: Überwald

More precisely, `hbl-append` aligns text using the bottom baseline in each pict, in case one pict is a vertical combination of other text `picts`. The `htl-append` function aligns text using top baselines.

2.2 Pict Abstractions

Since we need to create several people in the graph, we should abstract the box construction into a function.

```
(define (person name home)  
  (cc-superimpose  
    (rectangle 80 30)  
    (v1-append  
      (hbl-append  
        (text "Name: " 'roman 6)  
        (text name 'roman 10))  
      (hbl-append  
        (text "Home: " 'roman 6)  
        (text home 'roman 10)))))
```

One obvious problem with this implementation is the hard-wired size of the rectangle. It should grow to match the size of the labels, plus a small amount of padding. To create a pict whose size depends on another pict's size, we can use `pict-width` and `pict-height`.

```
(define (person name home)  
  (let ([content  
        (v1-append  
          (hbl-append (text "Name: " 'roman 6)  
                       (text name 'roman 10))  
          (hbl-append (text "Home: " 'roman 6)  
                       (text home 'roman 10)))]])  
    (cc-superimpose  
      (rectangle (+ 10 (pict-width content))  
                  (+ 10 (pict-height content)))  
      content)))
```

Name: Angua
Home: Überwald

```
(define angua  
  (person "Angua" "Überwald"))
```

```
(define brutha  
  (person "Brutha" "Omnia"))
```

Name: Brutha
Home: Omnia

At this point, we can create several people, plus the cloud and starting arrow, and combine them in a picture. If we just use `vc-append` and `hc-append` to combine the people, the layout will look too regular. We can use `inset` to wrap varying, extra space around some people; the `inset` takes a pict and either one argument for an amount of space to add around the pict, two arguments for separate horizontal and vertical space, or four arguments for separate left, top, right, and bottom space. We can also use a blank pict to put extra space between the people.

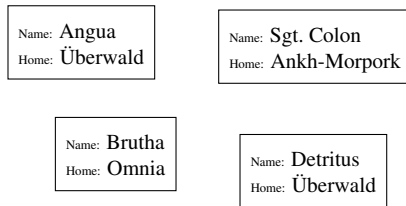
```
(define angua+brutha (vr-append
  (inset angua 10 10 10 0)
  (blank 0 18)
  brutha))

(define colon (person "Sgt. Colon" "Ankh-Morpork"))

(define detritus (person "Detritus" "Überwald"))

(define others (cloud 40 25))

(define people
  (hc-append
    angua+brutha
    (blank 20 0)
    (inset (vl-append
      colon
      (blank 0 24)
      (inset detritus 10 0 0 0))
      0 20 0 0)
    (blank 20 0)
    others))
```



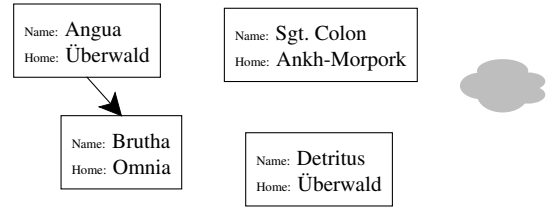
2.3 Finding Picts

To add an arrow from Angua to Brutha, we could insert an arrow pict into the `vr-append` sequence, but adding an arrow from Brutha to Sgt. Colon is not so straightforward with stacking operations. Slideshow provides a more general way to extend a pict, which is based on finding the relative location of sub-picts. Each pict has an identity (in the sense of Scheme's `eq?`), and all pict-combining operations preserve that identity internally. To locate a sub-pict within an aggregate pict, Slideshow provides a family of operations beginning with `find-`.

The suffix of a `find-` operation indicates which corner or edge of the sub-pict to find; it is a combination of l, c, or r (i.e., left, center, or right) with t, tl, c, or bl, b (i.e., top, top baseline, center, bottom baseline, or bottom). The results of a `find-` operation are the coordinates of the found corner/edge relative to the aggregate pict.

A `find-` operation is often combined with `place-over`, which takes a pict, horizontal and vertical offsets, and a picture to place on top of the first pict. For example, we can create a connecting arrow with `arrow-line` (which takes horizontal and vertical displacements, plus the size of the arrowhead) and place it onto `people`.

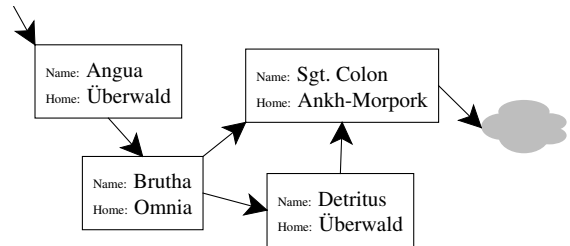
```
(let-values ([[ax ay] (find-cb people angua)]
  [[bx by] (find-ct people brutha)])
  (place-over
    people ax (- (pict-height people) ay)
    (arrow-line (- bx ax) (- by ay) 10)))
```



Since we need to create many people, we abstract the connection code. Different connections will connect to different parts of of the source and destination people, so our `conn` function accepts the relevant `find-` procedures as arguments.

```
(define (conn main from find-from to find-to)
  (let-values ([[ax ay] (find-from main from)]
    [[bx by] (find-to main to)])
    (place-over
      main ax (- (pict-height main) ay)
      (arrow-line (- bx ax) (- by ay) 10))))

(define graph
  (let* ([p (conn people people find-lt angua find-lt)]
    [p (conn p angua find-cb brutha find-ct)]
    [p (conn p brutha find-rt colon find-lb)]
    [p (conn p brutha find-rc detritus find-lc)]
    [p (conn p detritus find-ct colon find-cb)]
    [p (conn p colon find-rc others find-lc)])
    p))
```

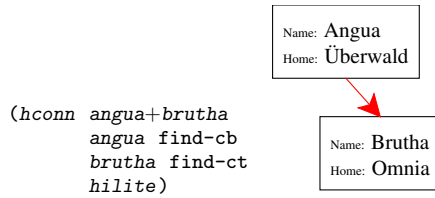


2.4 Colors and Line Widths

The graph pict so far corresponds to the initial slide in our demonstration. To illustrate depth-first search, we need to highlight arrows in the picture as the algorithm traverses links. We might implement this highlighting using the `find-` operations, re-drawing arrows to add color. More simply, we can parameterize our existing code to add highlighting. For example, we can generalize `conn` to accept a highlighting/dimming function that gives the arrow a color.

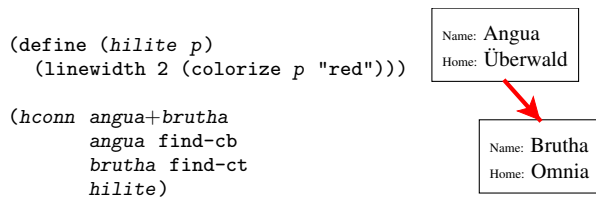
```
(define (hconn main from find-from to find-to hi/dim)
  (let-values ([[ax ay] (find-from main from)]
    [[bx by] (find-to main to)])
    (place-over
      main ax (- (pict-height main) ay)
      (hi/dim (arrow-line (- bx ax) (- by ay) 10)))))

(define (dim p) (colorize p "gray"))
(define (hilite p) (colorize p "red"))
```



In general, a pict is constructed to use certain default attributes, such as the width for lines and the color for drawing. The `colorize` operation overrides the default color (but it does not affect pict where the default is already overridden).

For arrows, a color change is a good start, but it does not adequately highlight a thin arrow (especially for readers of this paper who printed the colored PS/PDF on a black-and-white printer). We can change `hilite` further to adjust the line width.

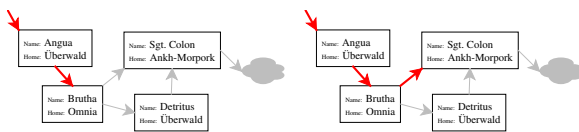


Finally, we assemble the connection additions into a function, and parameterize it over the highlighting function for each arrow. By calling `add-lines` with different arguments, we can generate a sequence of pictures to use in a sequences of slides that illustrate how a search algorithm traverses links.

```
(define (add-lines p ih abh bch bdh dch coh)
  (let* ([p (hconn p p find-lt angua find-lt ih)]
        [p (hconn p angua find-cb brutha find-ct abh)]
        [p (hconn p brutha find-rt colon find-lb bch)]
        [p (hconn p brutha find-rc detritus find-lc bdh)]
        [p (hconn p detritus find-ct colon find-cb dch)]
        [p (hconn p colon find-rc others find-lc coh)])
    p))

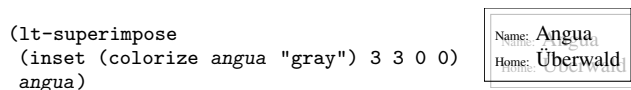
(define graph2
  (add-lines people hilite hilite dim dim dim dim))

(define graph3
  (add-lines people hilite hilite hilite hilite dim dim dim))
```

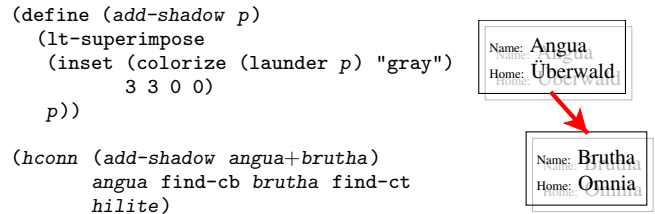


2.5 Functional Picts and Identity

The `colorize` and `linewidth` operations are functional, so they produce a new pict rather than modifying an existing pict. The functional nature of pict means that they can be used multiple times in constructing an image. For example, we can add a shadow to people by creating a gray version that is behind and below the black version.

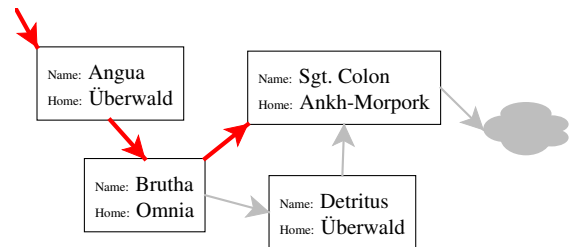


In the resulting pict, however, a `find-` operation for `angua` is ambiguous; it might find the black instance, or it might find the gray instance. The `launder` primitive takes a pict and produces one that is drawn the same as its input, but with no `find-able` sub-picts. By using `launder`, we can provide a shadow for the graph without interfering with the way that connecting lines are drawn.



The complement of `launder` is `ghost`. The `ghost` function creates a pict with the dimensions and sub-pict locations of a given pict, but with no drawing. For example, if we want just the arrows of the graph without the people, we can `ghost` out the `people`. This operation might be used, for example, to increase the default width of the arrow lines without affecting the default width of the person-box lines.

```
(lt-superimpose
  people
  (linewidth
    1 ; affects arrows, not boxes
    (add-lines (ghost people)
               hilite hilite hilite dim dim dim)))
```



2.6 More Abstractions

The graph example illustrates all of the properties of a pict: it has a bounding box, upper and lower baselines for text alignment, sub-pict locations, and a drawing procedure. In general, a drawing abstraction may require additional properties, and they can be implemented as a new abstraction that encapsulates pict.

In particular, instead of manually highlighting links to create `graph2` and `graph3`, we would prefer to represent the figure as an actual graph of records, and then implement depth-first search to highlight certain links. We therefore replace `add-lines` with a graph definition and search function.

To implement the graph, we first define record types for nodes and edges.

```
(define-struct node (p edges))

(define-struct edge (from find-from to find-to))
```

The declaration of `node` introduces the constructor `make-node` and the selectors `node-p` (for the node's picture) and `node-edges` (for the node's outgoing edges). The declaration of `edge` similarly introduces the constructor `make-edge` and selectors `node-from`, etc.

In addition to its start and end nodes, an edge includes *find-from* and *find-to* fields for drawing the edge with *hconn*.

Using the new record constructors and PLT Scheme's *shared* extension of *letrec*, we can define the graph of people.

```
(define nodes
  (shared ([i (make-node people
    (list (make-edge i find-lt a find-lt)))]
    [a (make-node angua
    (list (make-edge a find-cb b find-ct)))]
    [b (make-node brutha
    (list (make-edge b find-rt c find-lb)
    (make-edge b find-rc d find-lc)))]
    [c (make-node colon
    (list (make-edge c find-rc o find-lc)))]
    [d (make-node detritus
    (list (make-edge d find-ct c find-cb)))]
    [o (make-node others (list))])
    i))
```

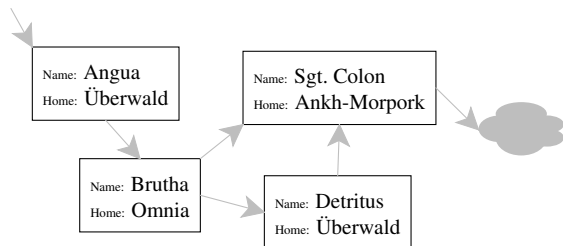
The following *search* function takes the current stack of edges, a list of previously visited edges (to avoid cycles), a target person to find, an initial value for the search's result, and a fold-like procedure for accumulating the result with each traversal of an edge.

```
(define (search edges seen target v traverse)
  (if (null? edges)
      v
      (let* ([e (car edges)]
             [next-v (traverse e v)]
             [new (remove* (append seen edges)
                           (node-edges (edge-to e)))]
             (if (eq? target (node-p (edge-to e)))
                 next-v
                 (search (append new (cdr edges))
                         (cons e seen)
                         target next-v traverse)))))
```

Using *search*, we can now define *graph* by adding a gray connection to *people* each time that we traverse an edge while exploring the entire graph.

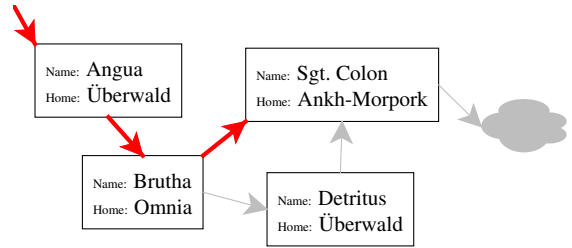
```
(define (line-adder h)
  (lambda (e p)
    (hconn p
      (node-p (edge-from e)) (edge-find-from e)
      (node-p (edge-to e)) (edge-find-to e)
      h)))

(define graph
  (search (node-edges nodes) (list)
    #f people (line-adder dim)))
```



We can then create *graph3* by searching for *colon*, re-adding connections along the way in highlight mode.

```
(define graph3
  (search (node-edges nodes) (list)
    colon graph (line-adder hilite)))
```



2.7 Direct Drawing and Scaling

Many pictures can be implemented purely with the functions described so far. For cases when the programmer wants direct access to the underlying drawing toolbox, Slideshow provides a *dc* constructor (where “dc” stands for “drawing context”). The *dc* function takes an arbitrary drawing procedure and bounding-box attributes. When the pict must be rendered, the drawing procedure is called with a target drawing context and offset.


For example, a *triangle* pict constructor can be implemented using the primitive *draw-line* method of a drawing context.

```
(define (triangle w h)
  (dc (lambda (dest x y)
    (let ([mid-x (+ x (/ w 2))]
          [far-x (+ x w)]
          [far-y (+ y h)])
      (send dest draw-line x far-y mid-x y)
      (send dest draw-line far-x far-y mid-x y)
      (send dest draw-line far-x far-y x far-y)))
    w h 0 0))
```

(triangle 20 10) 

The primitive drawing context is highly stateful, with attributes such as the current drawing color and drawing scale. Not surprisingly, slides that are implemented by directly managing this state are prone to error, which is why we have constructed the pict abstraction. Nevertheless, the state components show up in the pict abstraction in terms of attribute defaults, such as the drawing color or width of a drawn line. In particular, the *linewidth* and *colorize* operators change the line width and color of a pict produced by *triangle*. One further aspect of the drawing context that can be controlled externally is the drawing scale.

The *scale* operator scales a pict to make it bigger or smaller. (Independent horizontal and vertical scales enable squashing and stretching, as well.) Like color and line widths, scaling is implemented by adjusting the scale of the underlying drawing context, so that *scale* affects pict generated by *dc*, as well as any other pict.

(scale graph 0.4 0.2) 

Although the underlying drawing context includes a current font as part of its state, a pict's font cannot be changed externally, unlike the pict's scale, color, or line width. Changing a pict's font would mean changing the font of sub-picts, which would in turn would cause the bounding box of each sub-pict to change in a complex way, thus invalidating computations based on the sub-pict boxes. We discuss this design constraint further in Section 6.

2.8 Pict Primitives

Overall, the following may be considered the primitives for Slideshow pict:

- `dc` — the main constructor of pict.
- `scale`, `linewidth`, and `colorize` — property-adjusting operations.
- `inset`, `lift`, and `drop` — bounding-box adjustments (where `lift` and `drop` adjust the top and bottom baselines).
- `place-over`, `launder`, and `ghost` — combination operators.
- `find-lt` — sub-pict finder.

All other pict operations can be implemented in terms of the above operations. (For historical reasons, the actual primitives are less tidy than this set, but Slideshow continues to evolve toward an implementation with this set as the true primitives.)

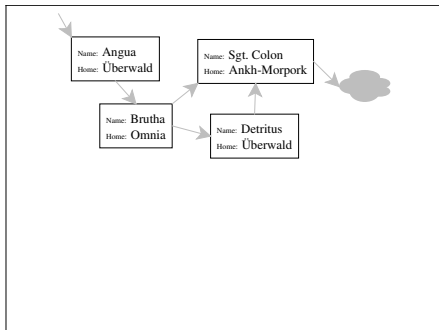
3 From Pictures to Slides

Picture-construction primitives are half of the story for Slideshow. The other half is a library of pict operations that support common slide tasks and that cooperate with a slide-display system. Common tasks include creating a slide with a title, creating text with a default font, breaking lines of text, bulletizing lists, and staging the content of a multi-step slide. Cooperating with the display system means correlating titles with a slide-selection dialog and enabling clickable elements within interactive slides.

3.1 Generating Slides

Abstractly, a slide presentation is a sequence of pict. Thus, a presentation could be represented as a list of pict, and a Slideshow program could be any program that generates such a list. We have opted instead for a more imperative design at the slide level: a Slideshow program calls a `slide` function (or variants of `slide`) to register each individual slide's content.¹

```
(slide
 (scale graph 3)) ; scale to fill the slide
```



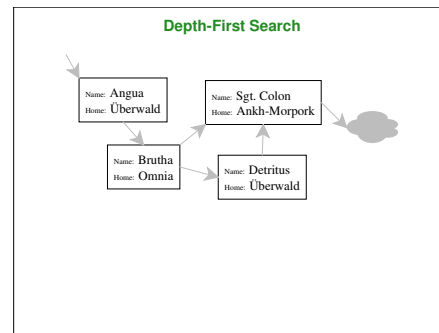
We choose imperative registration through `slide` because a slide presentation is most easily written as a sequence of interleaved definitions and expressions, much like the examples in Section 2. A programmer could thread a list through the sequence, but such a threading is awkward to read and maintain. The pict that are reg-

¹We illustrate the effect of `slide` by showing a framed, scaled version of the resulting slide's pict.

istered for slides remain purely functional (i.e., they cannot be mutated), so a small amount of imperative programming causes little problem in practice. Furthermore, we usually write `slide` at the top-level, interspersed with definitions, so each use of `slide` feels more declarative than imperative.

The `slide/title` function is similar to `slide`, except that it takes an extra string argument. The string is used as the slide's name, and it is also used to generate a title pict that is placed above the supplied content pict. The title pict uses a standard (configurable) font and is separated from the slide content by a standard amount.

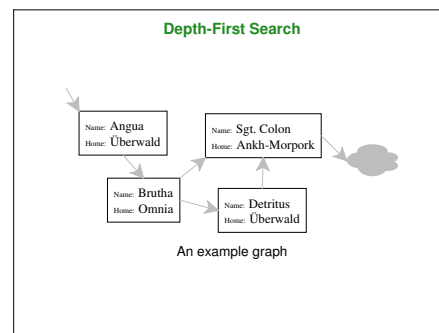
```
(slide/title "Depth-First Search"
 (scale graph 3))
```



In principle, the `slide` and `slide/title` functions simply register a slide, and programmers could build more elaborate abstractions in terms of these functions. In practice, programmers will prefer to use the more elaborate abstractions, and part of Slideshow's job is to provide the most useful of such abstractions. Thus, Slideshow allocates the relatively short names `slide`, `slide/title`, etc. to functions that provide additional functionality.

The most simplest such addition is that each `slide` function takes any number of pict, and it concatenates them with `vc-append` using a separation of `gap-size` (which is 24). The `slide` function then `ct-superimposes` the appended pict with a blank pict representing the screen (minus a small border). The `slide/center` function is like `slide`, except that it centers the slide content with respect to the screen. The `slide/title/center` accepts a title and also centers the slide.

```
(slide/title/center "Depth-First Search"
 (scale graph 3)
 (text "An example graph" 'swiss 32))
```



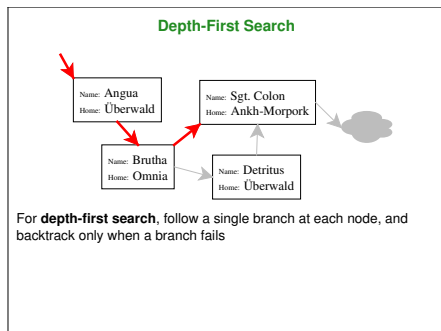
The set of pre-defined `slide` layouts includes only the layouts that we have found to be most useful. Programmers can easily create other layouts by implementing functions that call `slide`.

3.2 Managing Text

In the spirit of providing short names for particularly useful abstractions, Slideshow provides the function `t` for creating a text pict with a standard font and size (which defaults to sans-serif, 32 units high). Thus, the label for the earlier example could have been implemented as `(t "An example graph")` instead of `(text "An example graph" 'swiss 32)`. The `bt` function is similar to `t`, except that it makes the text bold, and it makes its text italic.

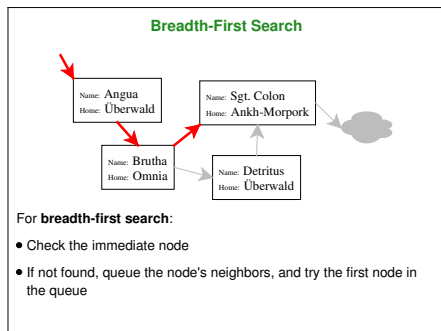
For typesetting an entire sentence, which might be too long to fit on a single line and might require multiple fonts, Slideshow provides a `para` function. The `para` function takes a width and a sequence of strings and `picts`, and it arranges the text and `picts` as a paragraph that is bounded by the given width. In the process, `para` may break strings on word boundaries. The `page-para` function is like `para`, but with a built-in width that corresponds to the screen's width (minus the margin).

```
(slide/title "Depth-First Search"
  (scale graph3 3)
  (page-para "For" (bt "depth-first search") ", "
    "follow a single"
    "branch at each node,"
    "and backtrack only when a branch fails"))
```



The `item` function is similar to `para`, except that it adds a bullet to the left of the paragraph. In parallel to `page-para` and `para`, the `page-item` function is like `item`, but with a built-in width that corresponds to the screen's width.

```
(slide/title "Breadth-First Search"
  (scale graph3 3)
  (page-para "For" (bt "breadth-first search") ":")
  (page-item "Check the immediate node")
  (page-item "If not found, queue the node's neighbors,"
    "and try the first node in the queue"))
```



Note that, given a bullet pict, `item` is easily implemented in terms of `para`.

```
(define (item w . picts)
  (html-append bullet
    (blank (/ gap-size 2) 0)
    (apply para
      (- w
        (pict-width bullet)
        (/ gap-size 2))
      picts)))
```

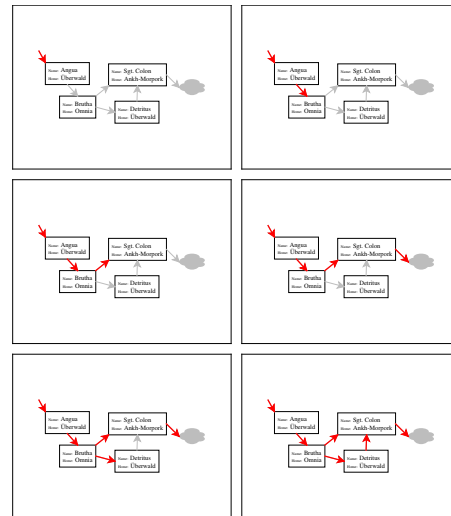
Just as Slideshow provides many `slide` variants, it also provides many `para` and `item` variants, including variants for right-justified or centered paragraphs and bulleted sub-lists. The `page-para*` function, for example, typesets a paragraph like `page-para`, but allows the result to be more narrow than the screen, so that it gets centered.

3.3 Staging Slides

In Section 2.4, we showed how to abstract a `pict`-constructing expression to support incremental changes to a `pict`. This technique can be used to implement any kind of “staged” slide, where parts of the screen are revealed or modified in a sequence of slides.

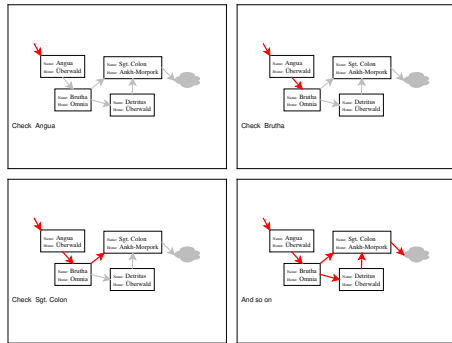
In some cases, a sequence of staged slides can be generated automatically. For example, we can use `slide/center` in a traversal with `search` to generate a sequence of slides that illustrates depth-first search.

```
(search (node-edges nodes) (list)
  #f graph (compose (lambda (x)
    (slide/center (scale x 3))
    x)
    (line-adder hilite)))
```



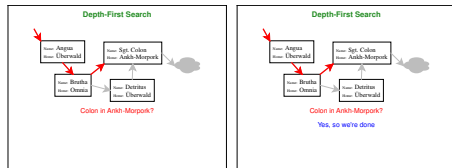
Few slide sequences are so automatic, however. To facilitate manual sequences, Slideshow provides a `with-steps` form that names each step in the sequence. Expressions in the body of `with-steps` can test whether the current step is before a particular step, after a particular step, or between two steps (inclusive or exclusive) to determine how to generate a slide. For example, we can use `with-steps` to generate a slide sequence with commentary that is specific to our sample graph of people.


```
(with-steps
  (a b c etc) ; step names to use in the body
  (slide/center
    (scale
      (add-lines people
        hilite
        (if (after? b) hilite dim)
        (if (after? c) hilite dim)
        (if (after? etc) hilite dim)
        (if (after? etc) hilite dim)
        (if (after? etc) hilite dim))
      3)
    (if (after? etc)
      (page-para "And so on")
      (page-para "Check " (cond
        [(only? a) "Angua"]
        [(only? b) "Brutha"]
        [(only? c) "Sgt. Colon"]))))))
```



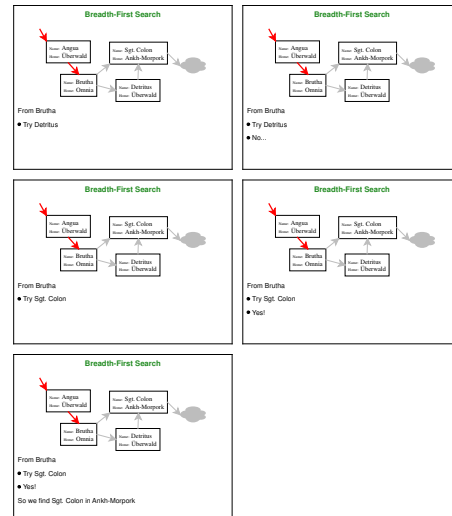
Much like text and hbl-append for typesetting paragraphs, with-steps is too primitive for staging bullets or lines of text on a slide. For example, when posing a question to students, an answer may be revealed only after the students have a chance to think about the question. To support this simple kind of staging, the slide function (and all its variants) treats the symbol 'next specially when it appears in the argument sequence. All of the pict's before 'next are first used to generate a slide, and then the pict's before 'next plus the arguments after 'next are passed back into slide to generate more slides.

```
(slide/title "Depth-First Search"
  (scale graph3 3)
  (colorize (page-para* "Colon in Ankh-Morpork?" "red")
    'next
    (colorize (page-para* "Yes, so we're done") "blue")))
```



Besides simple linear staging with 'next, the slide function supports staging with alternatives that are later abandoned. The 'alts symbol triggers this mode of staging. The argument following 'alts must be a list of lists, instead of a single pict. Each of the lists is appended individually onto the preceding list of pict to generate a slide. The final list is further appended onto the remaining arguments (after the list of lists). The 'next and 'alts symbols can be mixed freely.

```
(slide/title "Breadth-First Search"
  (scale graph2 3)
  (page-para "From Brutha")
  'alts
  (list (list (page-item "Try Detritus")
    'next (page-item "No..."))
    (list (page-item "Try Sgt. Colon")
    'next (page-item "Yes!"))))
  'next
  (page-para "So we find Sgt. Colon in Ankh-Morpork"))
```

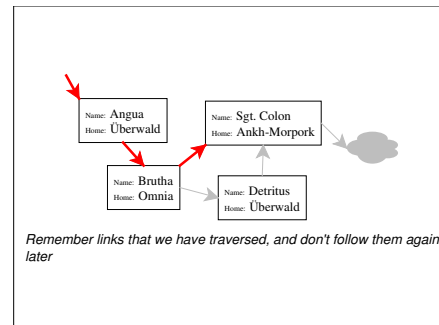


3.4 Adjusting Slide Defaults

As we noted in Section 2.7, the font used by a pict cannot be changed after the pict is created, because the pict's size depends on its font. At first glance, this constraint might limit the use functions like para, which do not accept a font specification and implicitly use t. Slideshow makes para and other functions more useful through implicit parameters for t. In particular, the font used by t (and bt and it) is determined by the current-main-font parameter, and the size is determined by the current-font-size parameter. A parameter's value can be set during pict creation using the parameterize form.

For example, if we want to typeset a paragraph as italics, we can use parameterize while constructing a pict with page-para*.

```
(slide/center
  (scale graph3 3)
  (parameterize ([current-main-font '(italic . swiss)])
    (page-para* "Remember links that we have traversed,"
      "and don't follow them again later")))
```



Slideshow provides several other parameters to control slide defaults, such as the `current-slide-assembler` parameter. It controls the overall style of a slide, including the background and the layout of titles, and it is typically set once per presentation.

3.5 Display Interaction

In addition to creating pictures for the screen, slide presenters must sometimes interact more directly with the display system:

- A slide author might wish to attach a commentary to slides, for the benefit of the speaker or for those viewing the slides after the talk. Slideshow provides a `comment` constructor that takes a commentary string and produces an object that can be supplied to `slide`. When the `slide` function finds a comment object, it accumulates the comment into the slide's overall commentary (instead of generating an image). The Slideshow viewer displays a slide's commentary on demand in a separate window.
- For presentations that involve demos, the speaker might like hyperlinks on certain slides to start the demos. Slideshow provides a `clickback` operator that takes a pict and a procedure of no arguments; the result is a pict that displays like the given one, but that also responds to mouse clicks by calling the procedure. (In this case, we exploit the fact that slide generation and slide presentation execute on the same virtual machine.)
- Although many “animations” can be implemented as multiple slides that the speaker advances manually, other animations should be entirely automatic. Currently, Slideshow provides only minimal support for such animations, though an imperative `scroll-transition` function that registers a scroll animation over the previously registered slide. (This feature has been used mainly to animate an algebraic reduction, making the expression movements easier to follow.) In the future, the pict abstraction might be enriched to support more interesting kinds of animation.

4 Rendering Slides

Slideshow is designed to produce consistent results with any projector resolution, as well as when generating PostScript versions of slides. The main challenges for consistency concern pict scaling and font selection, as discussed in the following sections. We also comment on Slideshow's ability to condense staged slides for printing, and to pre-render slides to minimize delays during a presentation.

4.1 Scaling

Since 1024x768 displays are most common, Slideshow defines a single slide to be a pict that is 1024x768 units. The default border leaves a 984x728 region for slide content. These units do not necessarily correspond to pixels, however. Depending on the display at presentation time, the pict is scaled (e.g., by a factor of 25/32 for an 800x600 display). If the display aspect is not 4:3, then scaling is limited by either the display's width or height to preserve the pict's original 4:3 aspect, and unused screen space is painted black.

Slideshow does not use a special file format for slide presentations. Instead, a Slideshow presentation is a program, and pict layouts are computed every time the presentation is started. Consequently, the target screen resolution is known at the time when slides are built. This information can be used, for example, to scale bitmap

images to match the display's pixels, instead of units in the virtual 1024x768 space. Information about the display is also useful for font selection.

4.2 Fonts

Fonts are not consistently available (or even consistently named) across operating systems. To avoid platform dependencies, Slideshow presentations typically rely on PLT Scheme's mapping of platform-specific fonts through portable “family” symbols, such as `'roman` (a serif font), `'swiss` (a sans-serif font, usually Helvetica), `'modern` (a fixed-width font), and `'symbol` (a font with Greek characters and other symbols). PLT Scheme users control the family-to-font mapping, so a Slideshow programmer can assume that the user has selected reasonable fonts. Alternately, a programmer can always name a specific font, though at the risk of making the presentation unportable.

Since specific fonts vary across platforms, displays, and users, the specific layout of picts in a Slideshow presentation can vary, due to different bounding boxes for text picts. Nevertheless, as long as a programmer uses `pict-width` and `pict-height` instead of hard-wiring text sizes, slides display correctly despite font variations. This portability depends on computing pict layouts at display time, instead of computing layouts in advance and distributing pre-constructed picts.

Text scaling leads to additional challenges. For many displays, a font effectively exists only at certain sizes; if a pict is scaled such that its actual font size would fall between existing sizes, the underlying display engine must substitute a slightly larger or smaller font. Consequently, a simple scaling of the bounding box (in the 1024x768 space) does not accurately reflect the size of the text as it is drawn, leading to overlapping text or unattractive gaps.

To compensate for text-scaling problems, Slideshow determines the expected scaling of slides (based on the current display size) before generating picts. It then uses the expected scale to generate a bounding box for text picts that will be accurate after scaling. Occasionally, the predicted scale is incorrect because the programmer uses the `scale` operation in addition to the implicit scale for the target display, but this problem is rare. When necessary, the programmer can correct the scale prediction by using the `scale/improve-new-text` form and creating text picts within the dynamic extent of this form.

4.3 Printing Slides

A drawing context in PLT Scheme is either a bitmap display (possibly offscreen) or a PostScript stream. Thus, printing a Slideshow presentation is as simple as rendering the slides to a PostScript drawing context instead of a bitmap context.

Slideshow provides a “condense” mode for collapsing staged slides. Collapse mode automatically ignores `'next` annotations; a programmer can use `'next!` instead of `'next` to force separate slides in condense mode. In contrast, `'alts` annotations cannot be ignored, because each alternative can show different information. A Slideshow programmer can indicate that intermediate alternatives should be skipped in condense mode by using `'alts~` instead of `'alts`.

Slideshow synchronizes page numbering in condensed slides with slide numbering in a normal presentation. In other words, when

slide skips a `'next` annotation, it also increments the slide number. As a result, a condense slide's number is actually a range, indicating the range of normal slides covered by the condensed slide.

Programmers can use the `condense?` and `printing?` predicates to further customize slide rendering for condense mode and printing. A `skip-slides!` function allows the programmer to increment the slide count directly.

4.4 Pre-rendering Slides

To avoid screen flicker when advancing slides in an interactive presentation, Slideshow renders each slide in an offscreen bitmap, and then copies the bitmap to the screen.

The time required to render a slide is rarely noticeable, but since a programmer can create arbitrary complex pict or write arbitrarily complex code that uses the drawing context directly, the rendering delay for some slides can be noticeable. To ensure instantaneous response in the common case, Slideshow pre-renders the next slide in the presentation sequence while the speaker dwells on the current slide. (If the speaker requests a slide change within half a second, the slide is not pre-rendered, because the speaker may be stepping backward through slides.)

5 Environment Support

Slideshow programs can be implemented using the DrScheme programming environment [4], since Slideshow is an extension of PLT Scheme. All of DrScheme's programming tools work as usual, including the on-the-fly syntax colorer, the syntax checker, the debugger, and the static analyzer. Non-textual syntax can be used in a Slideshow program, such as a test-case boxes, comment boxes, or XML boxes (which support literal XML without concern for escape characters) [2]. More importantly, we can use DrScheme's extension interface to add new tools to DrScheme that specifically support slide creation.

Figure 1 shows two screen dumps for one such tool. The tool keeps track of pict that are generated during the run of a Slideshow program, and then allows a programmer to move the mouse over an individual expression to see the pict(s) generated the expression. The black rectangles indicate mouseable positions. In the first screen dump, the mouse is over the `content` variable in `node`, and on the right, the four result pictures are shown—one for each call to `node` when the program is executed. In the second screen dump, the mouse is over the `rectangle` call, so four rectangles are shown to the right, and the size of each rectangle matches the size of each corresponding `content` pict. Moving the mouse over one of the calls to `code` would show a single pict, which is the boxed-content result of the call. (The `cc-superimpose` call in `code` is in tail position. To avoid turning loops into deep recursion, our prototype tool ignores tail expressions.)

Screen dumps for non-textual slide syntax appear in Figure 2. The value for the `nodes` definition is expressed using a `pict box`, as indicated by the icon in the top-right of the box. For the first screen dump, inside the pict box are five purple *Scheme* boxes, as indicated by the comma (suggestive of `unquote`) in the top-right. Each Scheme box escapes from pict mode back into Scheme. The programmer created each Scheme box, dragged it into place relative to other Scheme boxes, and then entered a Scheme expression into each box. When the pict box is evaluated, the expressions within Scheme boxes are evaluated to obtain sub-picts, and these sub-picts

are combined using the relative positions of Scheme boxes in the overall pict box.

Thus, the pict box in the screen dump implements the node layout that we created with `vr-append` and `hc-append` in Section 2.2, and interactive placement seems more natural in this case than programmatic stacking. For a full WYSIWYG treatment, the programmer needs to see the pict results for each Scheme box, rather than the Scheme code. The second screen dump in Figure 2 shows the same tool and program in “preview” mode, which uses results for the Scheme boxes (from a recent execution) to show a preview of the pict result. The Sgt. Colon box is highlighted because the programmer has just moved it, using preview mode to pick a better arrangement.

These slide-specific tools have yet to evolve beyond the experimental stage, but they illustrate how a programming environment can provide WYSIWIG-style tools that complement the language's abstraction capabilities.

6 Slideshow Design and Related Work

Slideshow's pict language is by no means the first language designed for generating pictures, and its picture constructors are similar to those of Henderson's functional pictures [6], MLgraph [1], Pictures [5], FPIC [8], `pic` [9], MetaPost [7], and many other systems. Unlike `pic` and MetaPost (but like MLgraph, etc.), Slideshow builds on a general-purpose programming language, so it can support modular development, it allows programmers to write maintainable code, libraries, and tests, and it is supported by a programming environment. MLgraph, Pictures, and FPIC provide a richer set of transformation operations (mainly because they all build on PostScript), while Slideshow provides a richer set of text-formatting operations. Also, Slideshow's combination of `find-`, `ghost`, and `launder` operations seems unique. The primary difference between Slideshow and other functional-picture languages, though, is that Slideshow has been refined through practice to meet the specific needs of slide creators.

In the IDEAL [13] picture language, programmers define pictures by describing constraints, such as “arrow X's endpoint is attached to box Y's right edge.” In Slideshow, the programmer effectively writes a constraint solver manually, using functions like `pict-width` and `find-lt`. We have opted for the more direct functional style, instead of a constraint-based language, because we find that many patterns of constraints are easily covered by basic combinators (such as `v1-append`), and other patterns of constraints (like adding lines to connecting node) are easily abstracted into new functions.

Our choice of direct computation, instead of using constraints, affects the kinds of properties that can be adjusted from outside a pict. As noted in Section 2.7, a pict's font cannot be changed externally, because changing the font would invalidate computations based on the pict's bounding box. In a constraint-based system, or where all primitive pict-combination operations are encapsulated in operations like `vc-append`, then invalidated computations can be re-executed. With more general combinations using `place-over`, however, the offsets are computed by arbitrary Scheme code, so that automatic re-calculation is not generally possible. Functional reactive programming [3] might be the right solution to this problem, and we intend to explore this possibility in future work. Meanwhile, Slideshow's current trade-off (flexible `place-over` versus inflexible fonts) has worked well in practice. If a pict needs to be

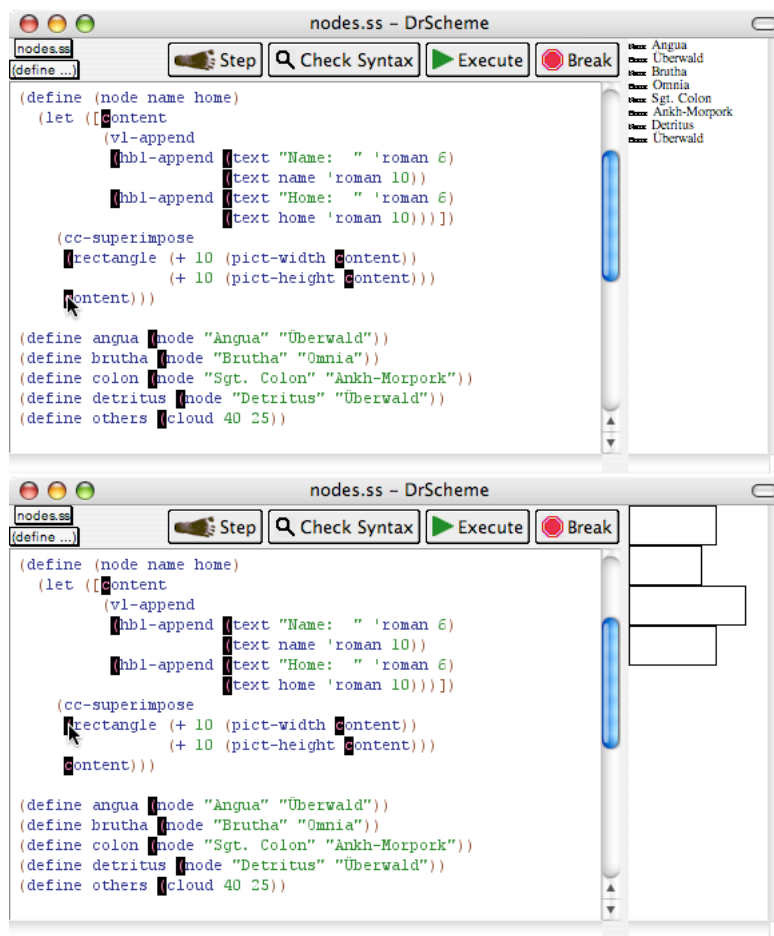


Figure 1. Mousing over expressions to see resulting pict

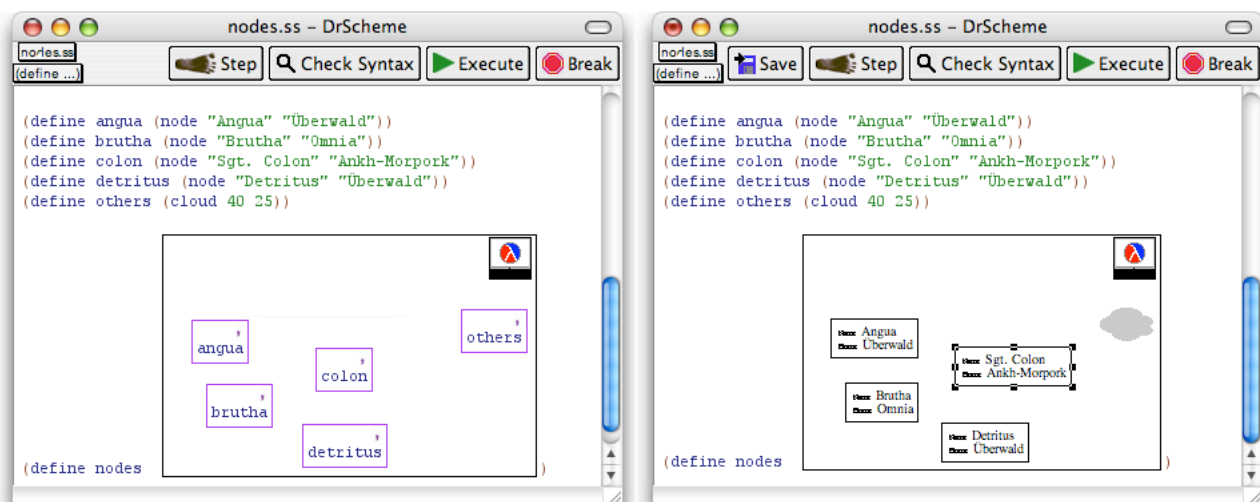


Figure 2. A pict box containing Scheme boxes

parameterized by its font, we simply use functional abstraction or `parameterize`.

Countless packages exist for describing slides with an HTML-like notation. Such packages typically concentrate on arranging text, and pictures are imported from other sources. Countless additional packages exist for creating slides with \LaTeX , including `foiltex` and `Prosper` [14]. With these packages, \LaTeX remains well adapted for presenting math formulae and blocks of text, but not for constructing pictures, and not for implementing and maintaining abstractions.

Like Slideshow, `Skribe` [11, 12] builds on Scheme to support document creation, but `Skribe` targets mainly the creation of articles, books, and web pages. Since `Skribe` includes a \LaTeX -output engine, it could be used to build slides through \LaTeX -based packages by adding appropriate bindings.

Unlike Slideshow, most slide-presentation systems (including all \LaTeX -based, PostScript-based, and PDF-based systems) treat the slide viewer as an external tool. Separating the viewer from the slide-generation language makes display-specific customization more difficult, and it inhibits the sort of integration with a programming environment that we advocate. An integrated viewer, meanwhile, can easily support executable code that is embedded within slides. Embedded code is particularly useful in a presentation about programming or about a software system, since an “eval” hyperlink can be inserted into any slide. More generally, Slideshow gives the presentation creator access to the complete PLT Scheme GUI toolbox, so practically anything is possible at presentation time.

7 Conclusion

In only the last few years, laptop-projected slides have become the standard vehicle for delivering talks, and tools other than PowerPoint are still catching up. We offer Slideshow as a remedy to PowerPoint’s lack of abstraction, HTML’s lack of flexibility, and \LaTeX ’s lack of maintainability. More generally, we believe that the time is ripe for a functional approach to slide construction, so we have reported on the constructs that we have found to work best.

Programmatic construction of pictures and slides is probably not for everyone (even with powerful programming-environment tools). For various reasons, many people will prefer to create pictures and slides in PowerPoint and without significant abstraction, no matter how nice the language of picture construction.

For the authors’ tastes and purposes, however, programmatic construction works well, and we believe that it appeals to many programmers. In our slides, with proper code abstraction, we can quickly experiment with different configurations of a picture, add slide-by-slide animation, and evolve ever more general libraries to use in constructing talks. Many tasks can be automated entirely, such as typesetting code and animating reduction sequences.

All of the figures in this paper are generated by Slideshow’s pict library, using exactly the code as shown.² In fact, like many other picture languages, Slideshow began as a system for generating figures for papers, and the core pict language works equally well on

paper and on slides. A picture language alone is not enough, however; most of our effort behind Slideshow was in finding appropriate constructs for describing, staging, and rendering slides.

For further information on using Slideshow and for sample slide sets (including slides for conference talks and slides for two courses), see the following web page:

<http://www.plt-scheme.org/software/slideshow/>

8 References

- [1] E. Chailloux, G. Cousineau, and A. Suárez. *The MLgraph System*, 1997.
- [2] J. Clements, M. Felleisen, R. B. Findler, M. Flatt, and S. Krishnamurthi. Fostering little languages. *Dr. Dobbs’s Journal*, pages 16–24, Mar. 2004.
- [3] C. Elliott and P. Hudak. Functional reactive animation. In *Proc. ACM International Conference on Functional Programming*, pages 263–273, 1997.
- [4] R. B. Findler, C. Flanagan, M. Flatt, S. Krishnamurthi, and M. Felleisen. DrScheme: A pedagogic programming environment for Scheme. In *Proc. International Symposium on Programming Languages: Implementations, Logics, and Programs*, pages 369–388, Sept. 1997.
- [5] S. Finne and S. Peyton Jones. Pictures: A simple structured graphics model. In *Proc. Glasgow Functional Programming Workshop*, July 1995.
- [6] P. Henderson. Functional geometry. In *Proc. ACM Conference on Lisp and Functional Programming*, pages 179–187, 1982.
- [7] J. D. Hobby. A user’s manual for MetaPost. Computer science technical report, AT&T Bell Laboratories, 1992. CSTR-162.
- [8] S. N. Kamin and D. Hyatt. A special-purpose language for picture-drawing. In *Proc. USENIX Conference on Domain-Specific Languages*, pages 297–310, Oct. 1997.
- [9] B. W. Kernighan. PIC — a graphics language for typesetting, user manual. Computer science technical report, AT&T Bell Laboratories, 1991. CSTR-116.
- [10] PLT. *PLT Scheme*. www.plt-scheme.org.
- [11] M. Seranno and E. Gallezio. *Skribe Home Page*. <http://www.inria.fr/mimosa/fp/Skribe>.
- [12] M. Seranno and E. Gallezio. This is Scribe! In *Proc. Workshop on Scheme and Functional Programming*, pages 31–40, Oct. 2002.
- [13] C. J. Van Wyk. IDEAL user’s manual. Computer science technical report, AT&T Bell Laboratories, 1981. CSTR-103.
- [14] T. Van Zandt. *Prosper*. prosper.sourceforge.net.

²We re-defined the `slide` operations to produce boxed `picts`, we scaled a few `picts` to save space, and we used Slideshow version 299.10, which includes minor improvements compared to the version 207 distribution.