Building an Embedded Linux Prototype

Devin Carraway, Chuck Groom

Blue Mug, Inc.

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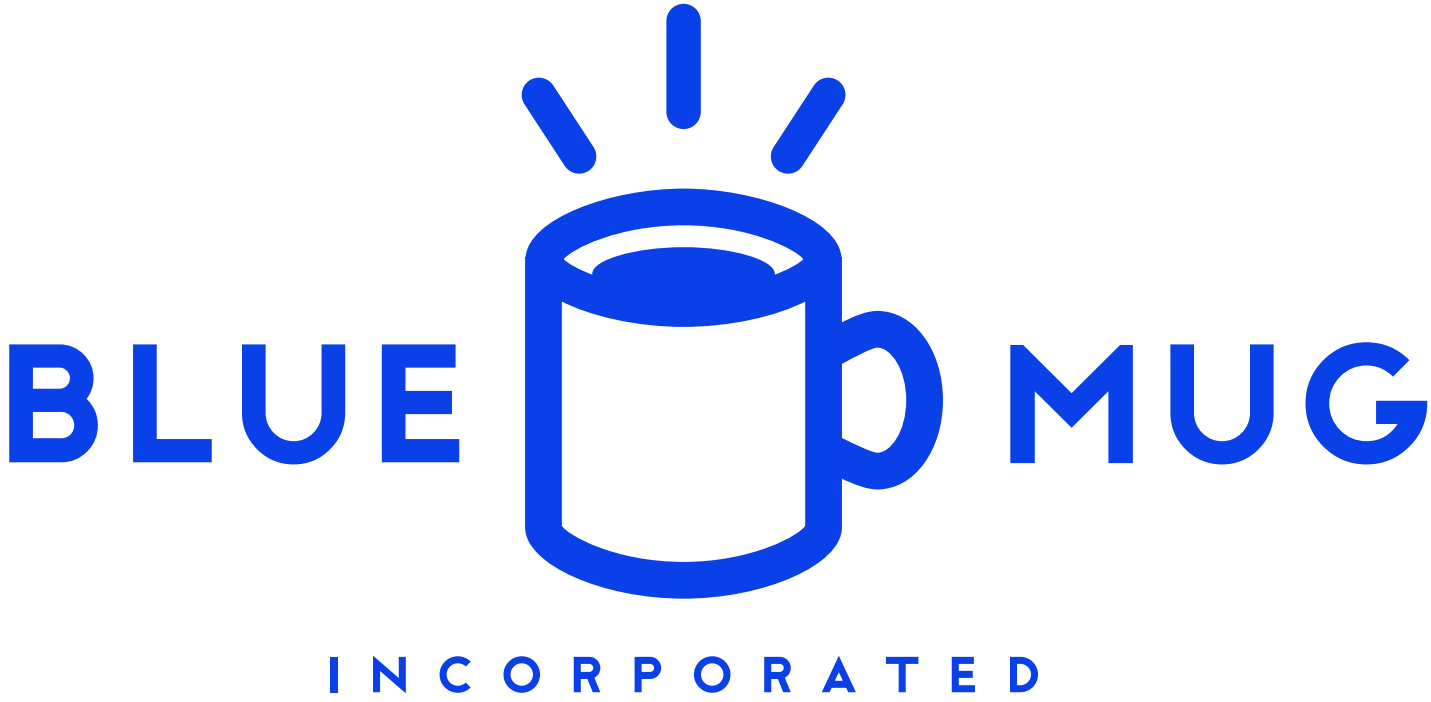
  - Embeddable Linux GUIs
  - Modifying Gtk+

About Us

Devin and Chuck are project engineers

- We write specs, design products, and write code
- Devin is... Linux master
- Chuck is “that user interface guy”

About Blue Mug, Inc.



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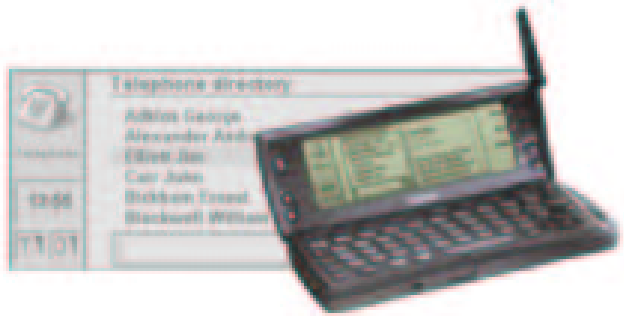

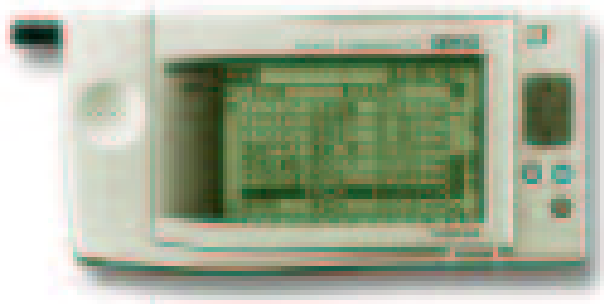

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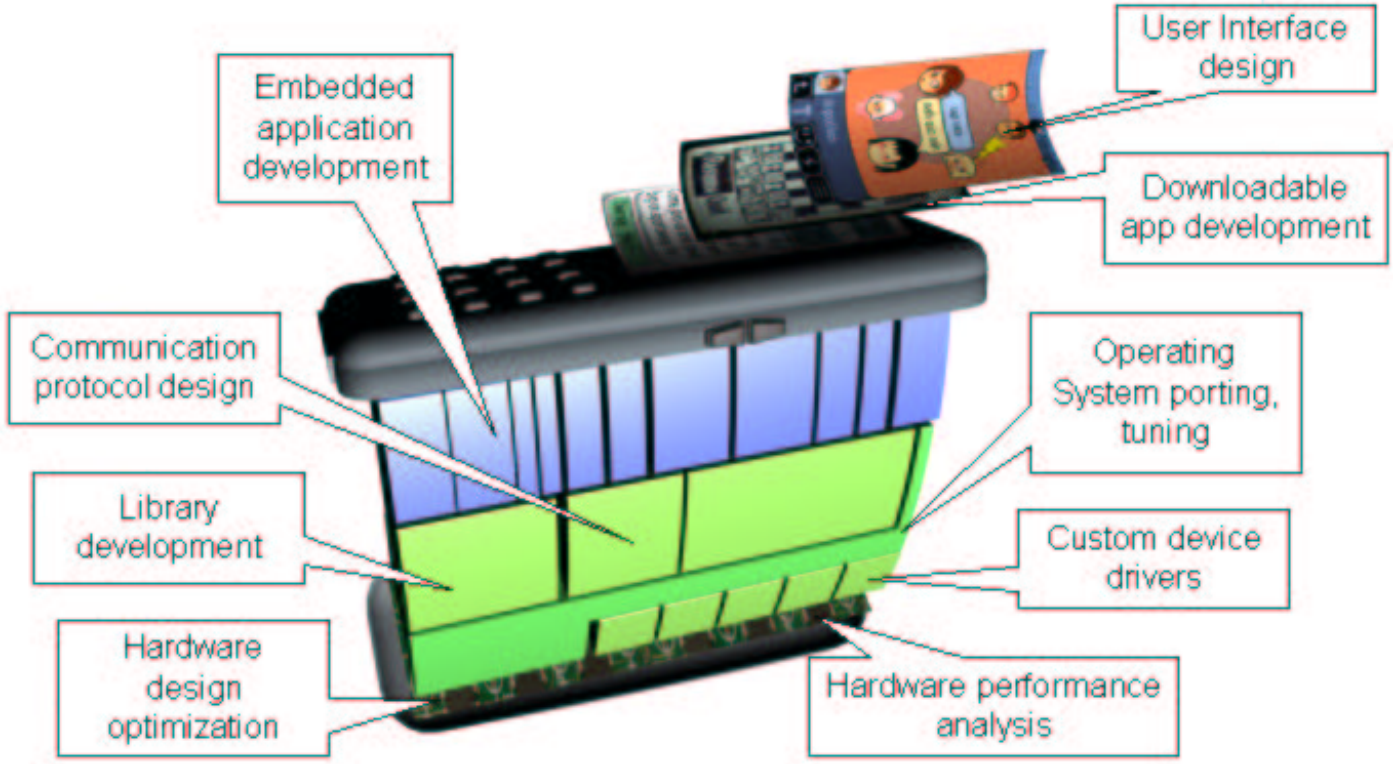

About Blue Mug, Inc.

Blue Mug creates software for mobile devices

- Located in Berkeley
- About 18 employees, 90% engineers
- Founded in 1999 (from Geoworks' Mobile OS Group)

About Blue Mug, Inc.

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We like Linux and embedded Linux, from several points of view:

- Business: free, not a dead-end technology
- Developer: sane platform
- Users: stable, doesn’t suck

About Blue Mug, Inc.

Blue Mug creates software for mobile devices

But we’re not a Linux-only company

- GEOS-SC OS
- PalmOS
- RTOS
- J2ME, BREW
- Small embedded projects

The Project

Our client asked us to create a prototype for a device:

- Low-cost (<$100)

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- Soft-key input
- Small gray-scale screen
- Palm-like battery life (22hrs)
- Can run simultaneous apps
- Multiple access points (modem, PCMCIA for Ethernet, Bluetooth, etc.)

Project Example Mockup

Hardware Selection

Which embeddable system-on-a-chip to use?

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Considerations:

- Performance
- Price
- Power consumption

Hardware Selection

Which embeddable system-on-a-chip to use?

StrongARM, PPC use too much power, cost too much

Hardware Selection

Which embeddable system-on-a-chip to use?

MIPS, SH are struggling

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We choose the Cirrus Logic EP7211 board.

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- 75Mhz ARM7
- 16Mb Flash, 16Mb RAM
- Low-power (170mw)
- Successor to PS7110 used in Psion Series 5, for which there is a Linux port.

System Overview

- Two 8Mb banks of Flash
  - Kernel in one bank
  - Root file system in other bank (mounted read-only)
- /tmp in RAM
- User files, add-on apps in RAM
- No swap!

Size/RAM issues

- Size: 8Mb for all libraries, GUI, windowing system, and apps

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- RAM usage
  - Could do XIP from RAM
  - Never ran out of RAM in testing

Out of Memory – What to do?

Low-Level: OOM

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Easier on embedded system

- Known set of processes (eg. BeOS' "kill the browser" approach)
- Tie into UI to display warning or errors
- Require apps to be aware of low-memory situations

Low-Level: Memory Mapping

EP7211 memory is non-contiguous

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- Use kernel macros to map between actual and linear presentation of memory

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Start with GLibC, move to sglibc.

User Interface: Design Principles

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Good: Palm UI fits small-screen, stylus-central organizer

Bad: WinCE UI presents entire desktop interface on small screen

User Interface: User Goals

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Always keep the user's goals in mind.

- Mobility = urgency
- Objective: get job done
- Technology: avoid unless necessary
- Status notification: don't alert unless problem
- Rich feature set: device feels unpredictable

User Interface: Givens

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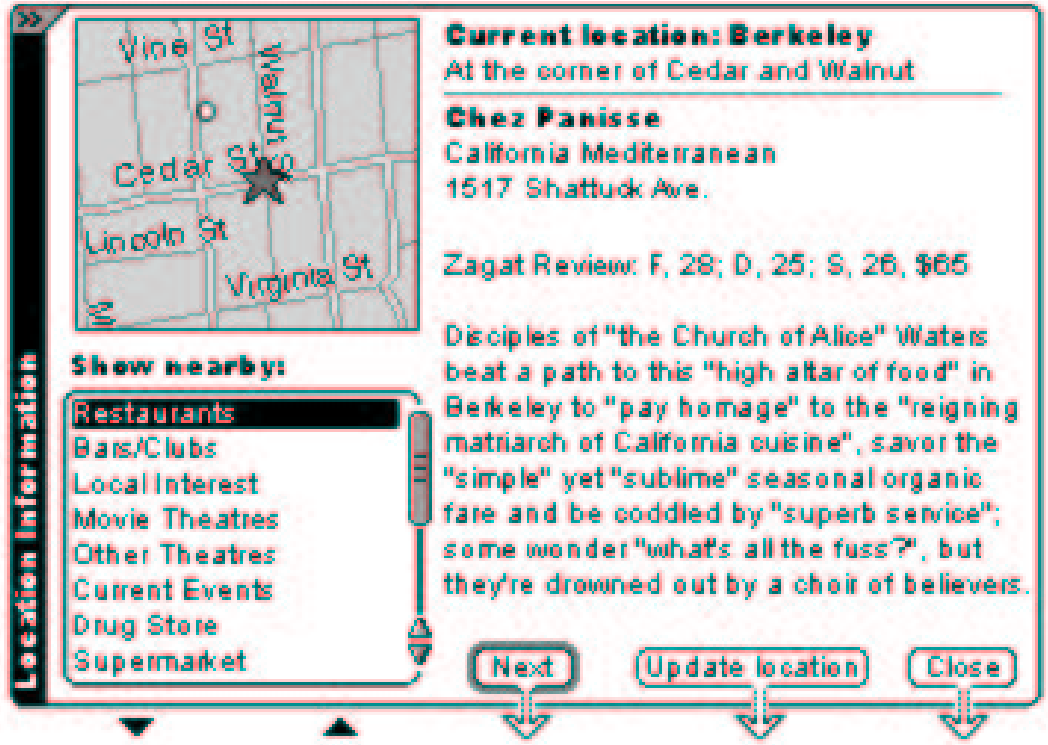
- “Walk up and use” interface
  - Borrow desktop elements as needed
  - Limit choices

User Interface: Our Design



(This is a conceptual mockup)

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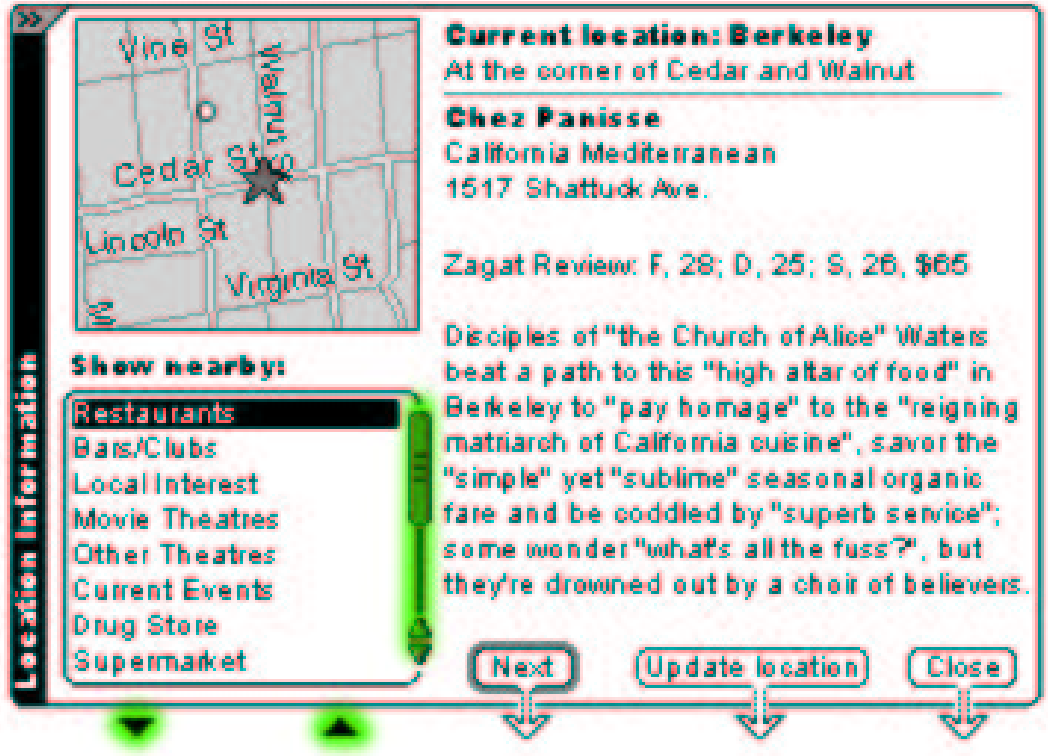

Use desktop GUI widgets with softkey control

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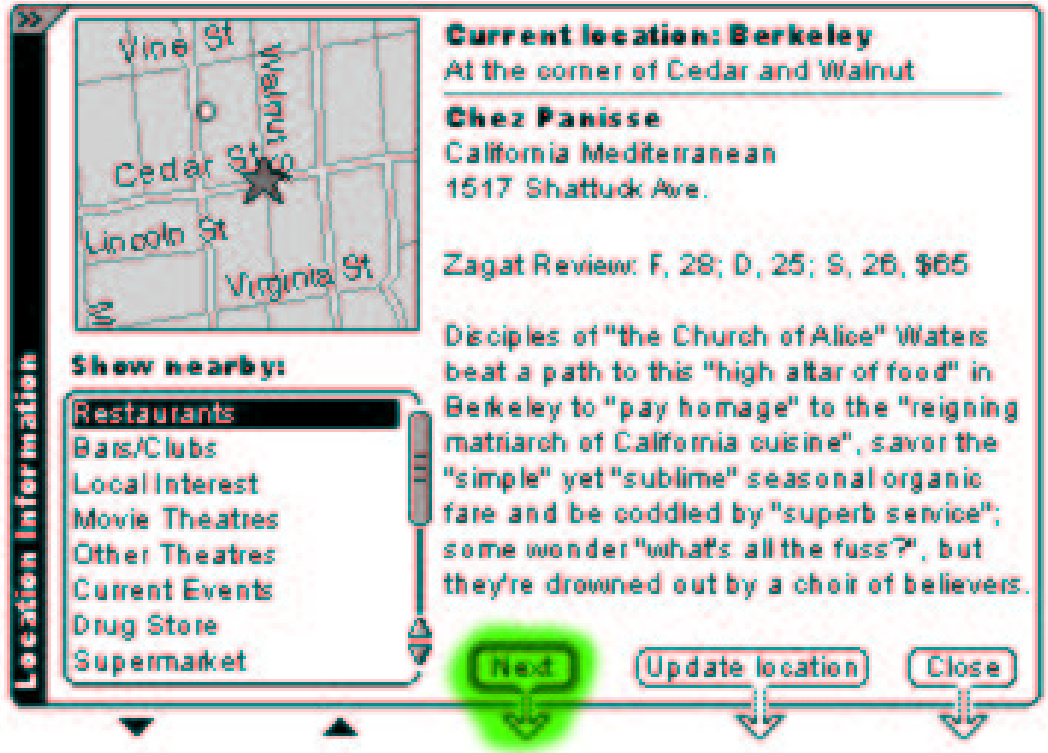

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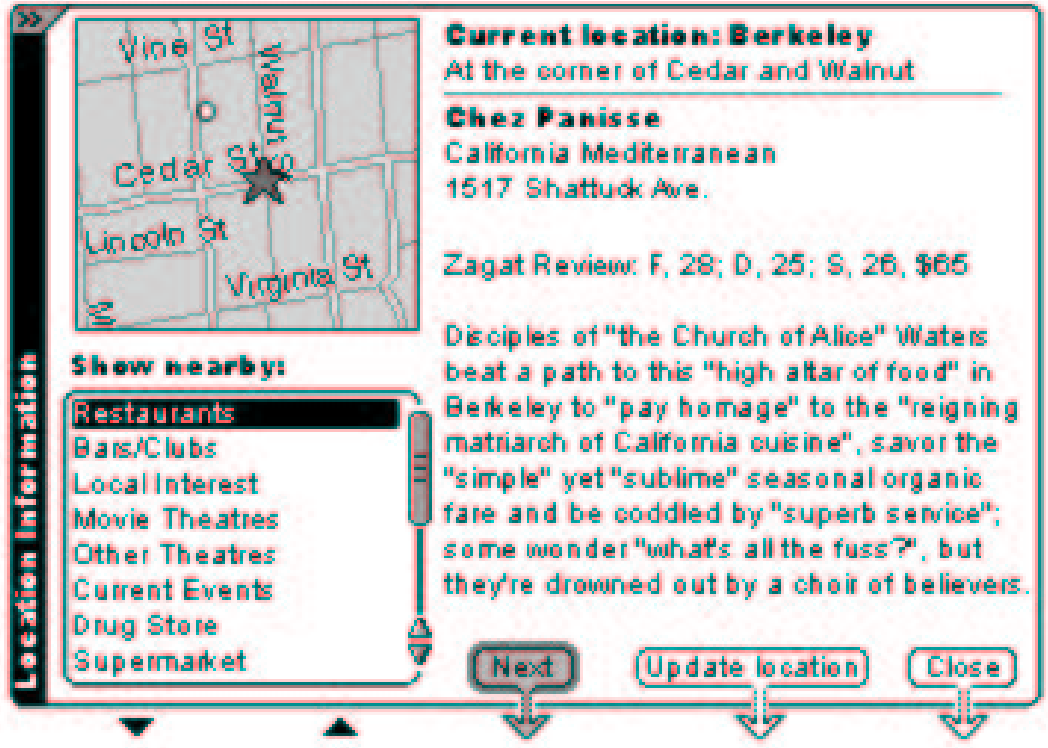

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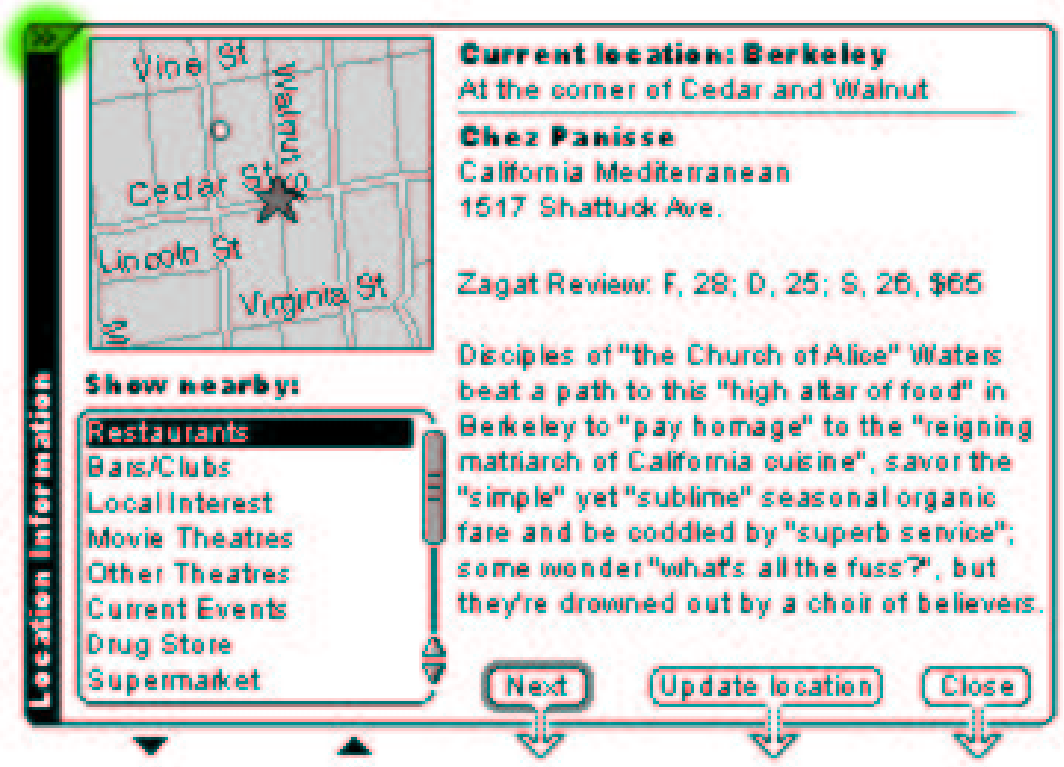

Place options in menu. Hide menu to save screen space, but indicate existence.

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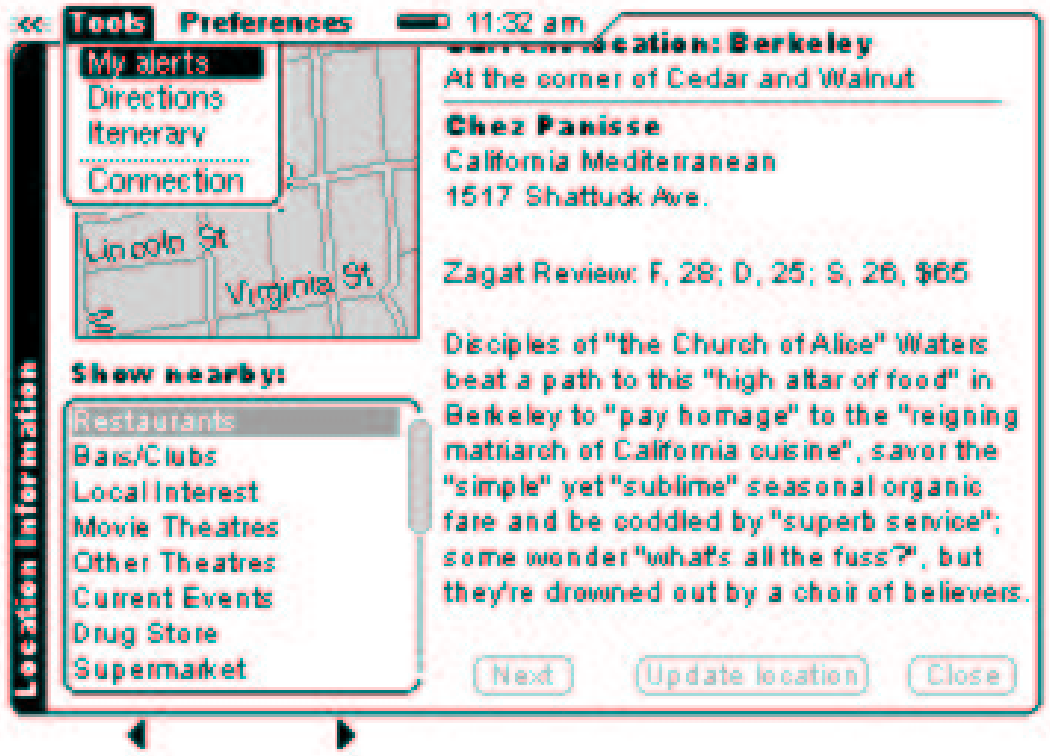

Menu bar includes time and battery.

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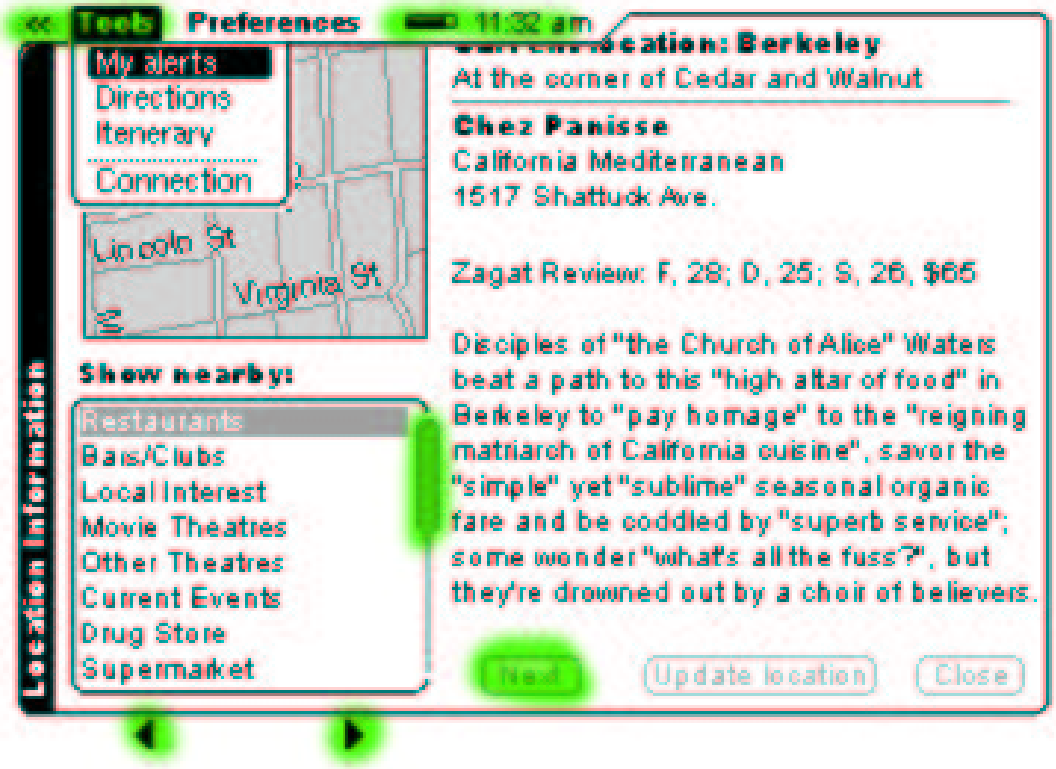

Menu is modal and takes control of softkey bar. Other widgets are inactive.

User Interface: Other Elements

Other misc. design elements...

- Softkeys vs. buttons.

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- Dialogs

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- Softkeys vs. buttons.
  - Softkeys can be stand-alone
  - Use buttons when action affects pane.
- Added “indeterminate” state to radio buttons, check boxes
- Dialogs
- When we launch an app, display “zoomy rectangle”

User Interface: Embeddable Linux GUIs

How do we implement this interface?

User Interface: Embeddable Linux GUIs

How do we implement this interface?

$\rightarrow$ Tweak existing UI. There are many possible Linux UIs to pick between.

User Interface: Embeddable Linux GUIs

Criteria:

- Completeness
- Size
- Multiple apps can access framebuffer
- Language (C, C++)
- License

User Interface: Embeddable Linux GUIs

- Gtk+
- Qt/e
- FLTK
- OpenGUI
- MiniGUI
- PicoGUI
- Microwindows
- ...

User Interface: Embeddable Linux GUIs

Narrowed to Gtk+ or Qt/e

User Interface: Embeddable Linux GUIs

Qt

- KDE Desktop
- Developed by TrollTech
- C++ framework
- Qt/E is reduced, runs on framebuffer
- QTopia app infrastructure
- Pain to compile
- Dual-license

User Interface: Embeddable Linux GUIs

Gtk+

- GNOME Desktop
- Open source project
- C
- Developed on X; also Gtk+/fb
- LGPL

User Interface: Embeddable Linux GUIs

Decided on Gtk+ running on X

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X Windows! Eek!

- Client-server windowing system
- Network-transparent
- 20 years old
- Widely regarded as bloated and archaic

User Interface: Embeddable Linux GUIs

Decided on Gtk+ running on X

We like X

- X is stable
- Network-transparency is helpful
- TinyX

User Interface: Embeddable Linux GUIs

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Modified AEWM window manager

- Vertical title bars
- Inter-app communication
- Application-level awareness of modal dialogs

User Interface: Modifying Gtk+

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Changes in-place, not sub-classed

User Interface: Modifying Gtk+

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2.9Mb footprint for Gtk+/X; this could be reduced to 2.4Mb.

User Interface: GtkWindow

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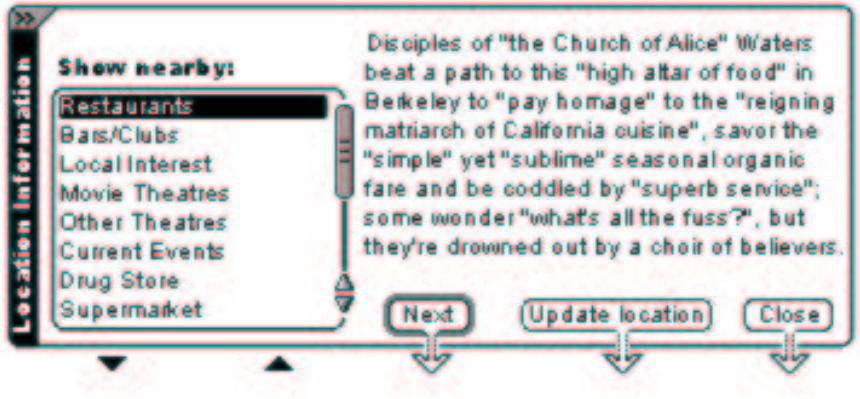

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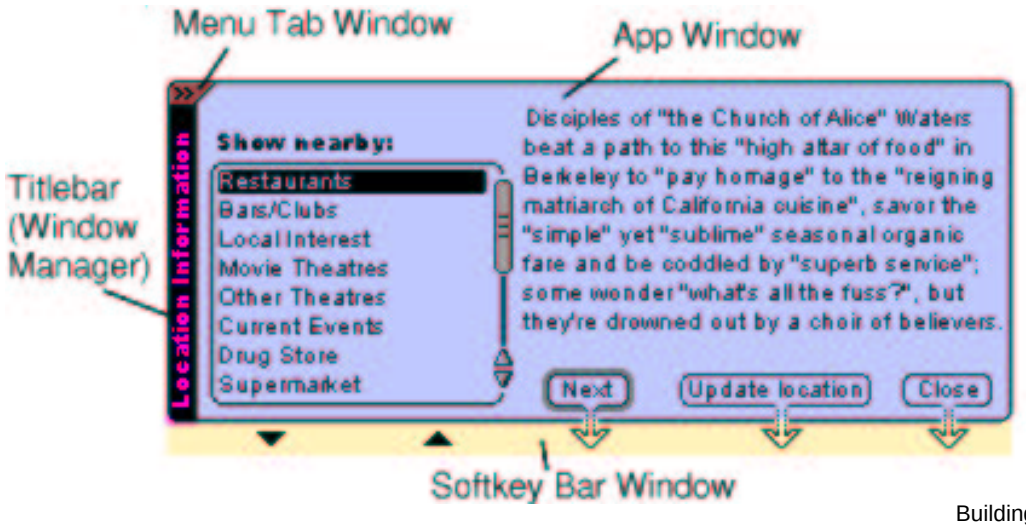

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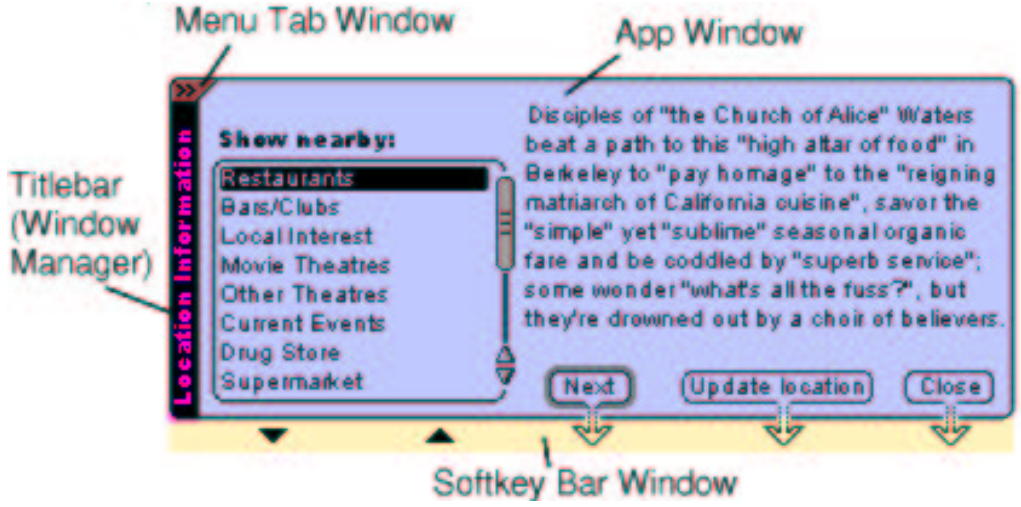

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User Interface: Font

To change a font in stock Gtk+:

- Clone widget's `GtkStyle`
- Load a new X font, such as `-adobe-helvetica-bold-r-normal-12-*-*-*-p-*-iso8859-1`

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GtkStyle is fairly big, so this is expensive. And the developer has to know the specific font name.

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You can request font changes even before Gtk+ knows the base font.

User Interface: Performance

- Slow launch times

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- Slow launch times
  - 2.4 seconds for most complicated app
  - Memory bandwidth bottleneck
  - For now, display eye candy when app is launched
  - In future, predictively launch applications

User Interface: Performance

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- Loading pixmaps

User Interface: Performance

- Slow launch times
- Loading pixmaps
  - XPM format is bulky
  - Gtk+’s XPM parser sucks
  - Hack parser
  - Hand post-rendered pixmaps to X server

User Interface: Performance

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User Interface: Performance

- Slow launch times
- Loading pixmaps
- Floating point calculations
  - Floating point calculations are expensive on ARM
  - Gtk+ uses floating points for widget positioning
  - Integer math positioning gives a 3-12% speedup

Conclusion

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- Questions?