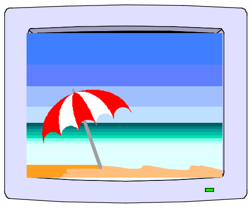
XXIII. User Interface Design

What is Human-Computer Interaction?
Affordances, Mappings, Mental Models,
Feedback, Forcing Functions, Learning
How to Design Interfaces
User Dialogue Design
Inputs and Outputs



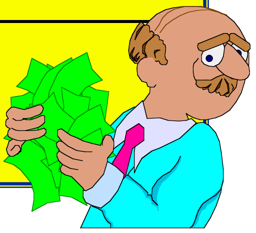
HCI = Human-Computer Interaction

Why should a Systems Analyst Know HCI?

- 40-60% of today's software does user interface management - high interactivity with the user, much end-user programming
- User interactivity is only going to get more complex
  - ✓ 3D graphics and Virtual Reality;
  - ✓ More augmented reality activities.
- Many of the problems with introducing and maintaining a system can be traced back to a bad interface design
  - ✓ Users sabotage systems they don't understand;
  - ✓ Users make more errors when dealing with systems that are difficult to use.
- A good user interface can reduce coding costs, reduce high costs of interface problems, reduce serious life-threatening errors, sell more products, lead to increased use of computers, more...

Increased Productivity

```
     20 users
X    230 days
X    100 screens per day
X    10 sec per screen (savings)
----------------------------------
=    1278 hours or 32 weeks
```

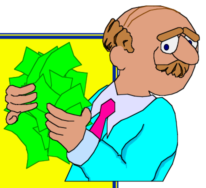


Reduced Training Costs

```
     20 employees
X    2 systems/applications per year
X    2 1/2 days per application (saved)
--------------------------------------
  =  100 days or 20 weeks of savings
```

Training and support often more costly than hardware and software

Preventable User Errors



500 users
X 20 errors per year
X 15 minutes per error

= 2500 hours lost or 63 weeks

Increased Productivity

500 menu selections per day
X 2 sec per selection (saved)
X 230 days per year

= 320 hours or 8 weeks

For a $100K person-year cost, saved time translates to $15,000

Serious Life-Threatening Errors

- Analysis of transcript of 911 call announcing bomb in Centennial Park at the Atlanta Olympics indicated that 20 minutes were needed to call dispatchers
  - ✓ Dispatch system required an address for Centennial Park;
  - ✓ Dispatch operators could not find anyone who knew address;
  - ✓ Bomb was set to go off 30 minutes after call.
- Airline crashed into a mountainside in Colombia in 1996, killing all aboard (including a well-known computer scientist and his whole family!)
  - ✓ Pilot typed in “R” rather than full name of airport
  - ✓ Guidance system took first airport in the list beginning with “R” which was the wrong airport
  - ✓ Plane ran into mountain...

User Interface Economics

- Good user interfaces sell systems!
  - ✓ Windows is a copy of the Macintosh interface;
  - ✓ The Mac interface is a copy of Bravo - developed by user interface researchers at Xerox PARC.
- User interface capabilities and awareness help get contracts.
- Poor user interfaces can cripple a system that is outstanding in all other respects.
- Computer-driven interfaces placed in most mechanical products we know
  - ✓ Classic problem of users not being able to set the clock on their VCR;
  - ✓ Users often can’t use a photocopy machine, a fax machine, a cash register, a candy machine, a bank machine or even a telephone;
  - ✓ Cars will eventually be completely computer driven...

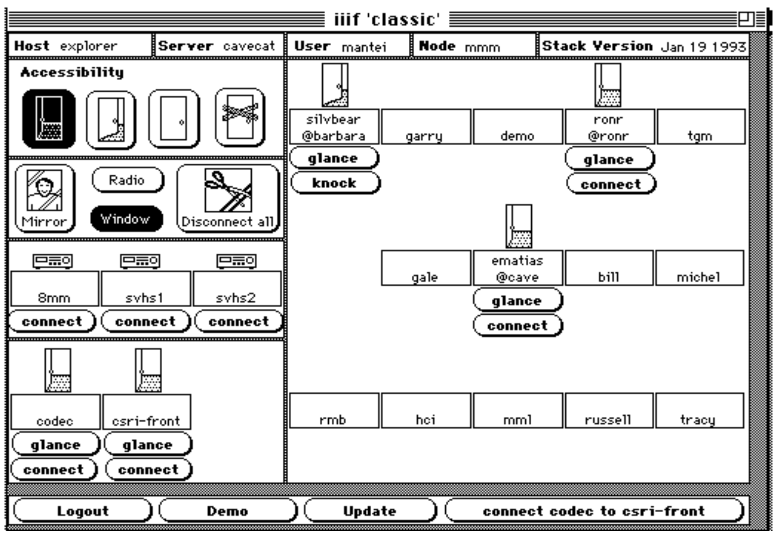
Why Are User Interfaces Poor?

- Inadequate training of people developing interfaces.
- Diversity of knowledge required to design good interfaces.
- Rapid technological advances.
- Reluctance of companies to commit resources.
- Poor management - programmers do not talk to user design teams and vice versa.
- User Interface specialists rarely involved.
- The "bricklayers" (programmers) are left to design the user interface, by default.

"Ignorance by software engineers of usability and how to measure it is roughly equivalent to an electronics engineer not knowing what volts and watts are and how to measure them."

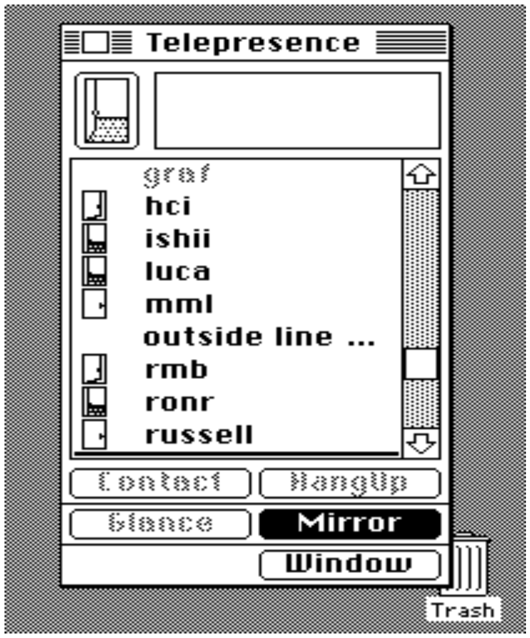
What's Wrong with this Interface?

Design of User Interface for CAVECAT Media Space



Why is this Design Better?

Design of User Interface for Telepresence Media Space



Some Basic Human Characteristics

- Humans like to problem solve, but don't like unsolvable problems!
- Humans are always learning, but learning is hard!
- Humans use prior learning to support new learning.
- Users don't read manuals but work by copying and asking.
- Users are always building models of their world.
- Implications
  - ✓ Build interfaces that allow people to ***learn by using*** the interface;
  - ✓ Build interfaces that suggest correct models;
  - ✓ Build interfaces that rely on prior learning.
- Users don't mind if something doesn't make sense -- they build their own model to make it make sense.
- Users prefer simple models.
- Inconsistency doesn't bother users -- A simple model which doesn't always match is better than a complex model that is too hard to learn.

Characteristics of a Good Design

The design of the user interface

- Has ***affordances*** - makes each operation visible;
- Offers obvious ***mappings*** - makes the relationship between the actual action of the device and the action of the user obvious;
- Provides ***feedback*** on the user's action;
- Provides a good ***mental model*** of the underlying behaviour of the device;
- Provides ***forcing functions*** -- prevents a user from making bad errors;
- Supports ***automatic learning*** -- provides consistencies and practice that help the user acquire interface skills.

Affordances

- ***Affordance*** of an artifact means that the design of the artifact in some way describes what the user can do with it, i.e., indicates what operation the user may perform.
- Good example of affordance -- buttons which indicate to the user that they are to be pressed
- Bad example of affordance -- the "put-away" box in the upper right hand corner of a Macintosh window.
- Well-known affordances:

  Glass is for looking through (...or breaking)

  Stairs are for climbing...

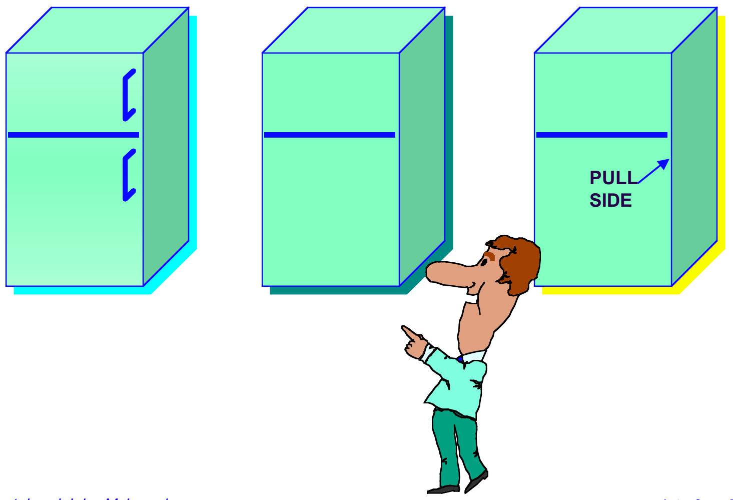
  Cardboard is for writing on...

  Radio buttons are for pushing or turning…

  Icons are for clicking…

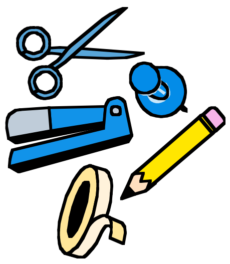
  Door handles are for pulling, door bars are for pushing...

Different Affordances

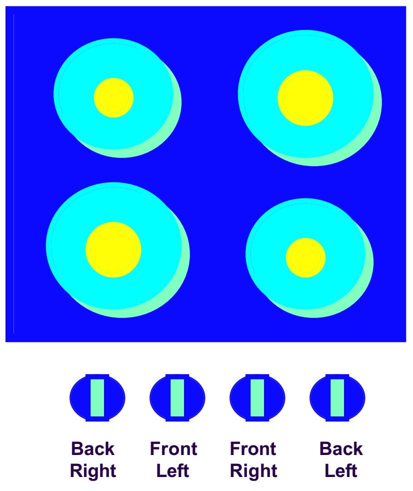


Mapping Functions

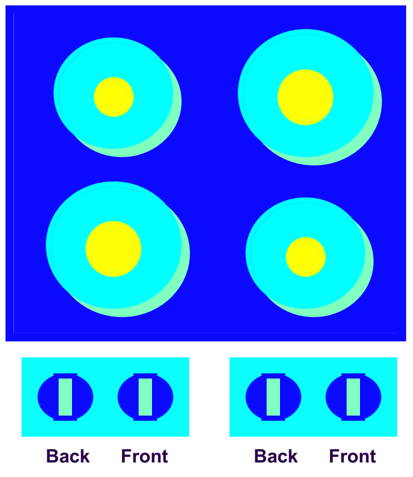
- ***Mapping Functionality*** - the design in some way shows a mapping between the intended use of the tool and the action of the underlying technology.
- Good example of mapping: -- the presentation of the font to be selected in the form and shape of the font.
- Bad example of mapping: function keys in general -- the mapping is totally arbitrary.



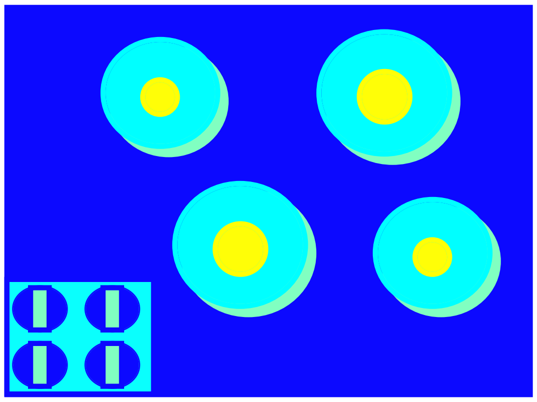
Some Designs are Better Than Others...



Paired Stove Controls



Fully Natural Mapping of Controls and Burners



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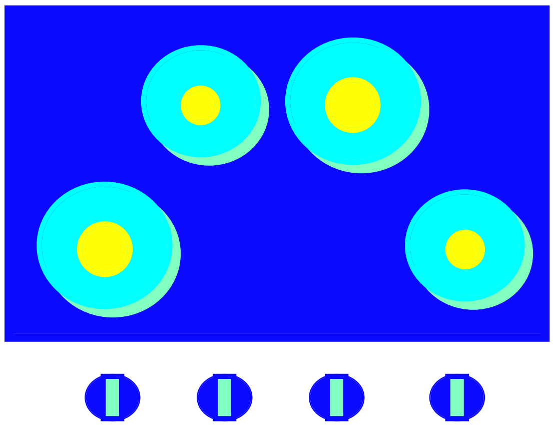


Mental Models

- ***Mental Model*** - the underlying understanding that a person has about how a technology or device works so that the user has some idea that if she performs action A, then event B will follow.
- Examples of incorrect mental models:
  - ✓ Some foreign students apply directly to a professor for graduate studies;
  - ✓ Some parents of foreign students try to find a friend within the university who will influence the admissions office.
- Good example of mental model usage:
  - WYSIWYG - What you see is what you get
- Example of systems with no mental model: ***online retrieval systems, extra functions on a telephone***

Forcing Functions

- ***Forcing Functions*** are designs that prevent users from taking actions which are inappropriate or which would lead to error
- Good example of a forcing function design:
  - the Macintosh menu bar - grays out and prevents the selection of those items inapplicable to the current context
- A bad example of a forcing function design:
  - Unix - every command is allowed as long as it is typed correctly
- Exercise: You buy some groceries on your way to work and put them in the office refrigerator; how do you make sure that you won't leave work without the groceries?

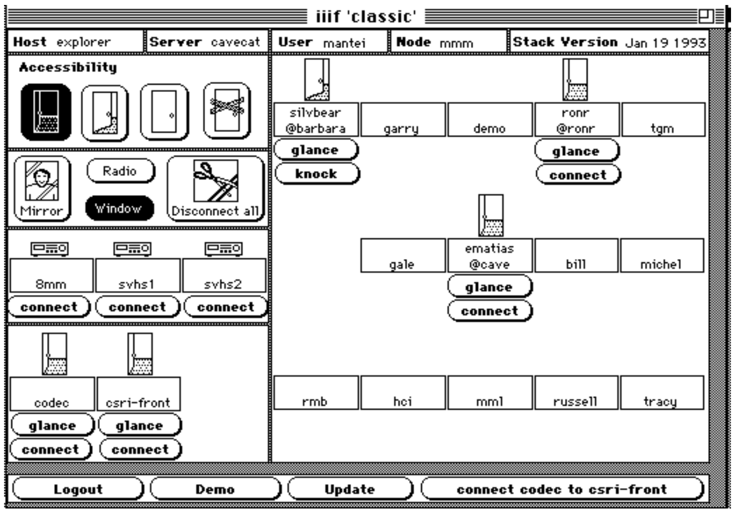
Feedback

- Feedback - a design in which a form of visual, auditory or other modality response is given *immediately* after the user action to indicate that the action has been received.
- Good example of feedback: icons on the screen which show a reverse video image when selected.
- Example of non-use of feedback : Latex and other text formatting systems.

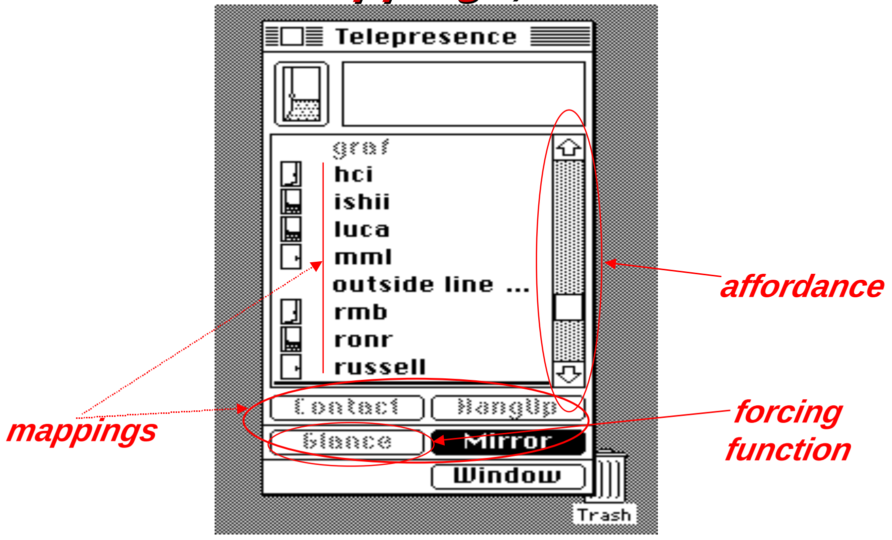
Automatic Learning

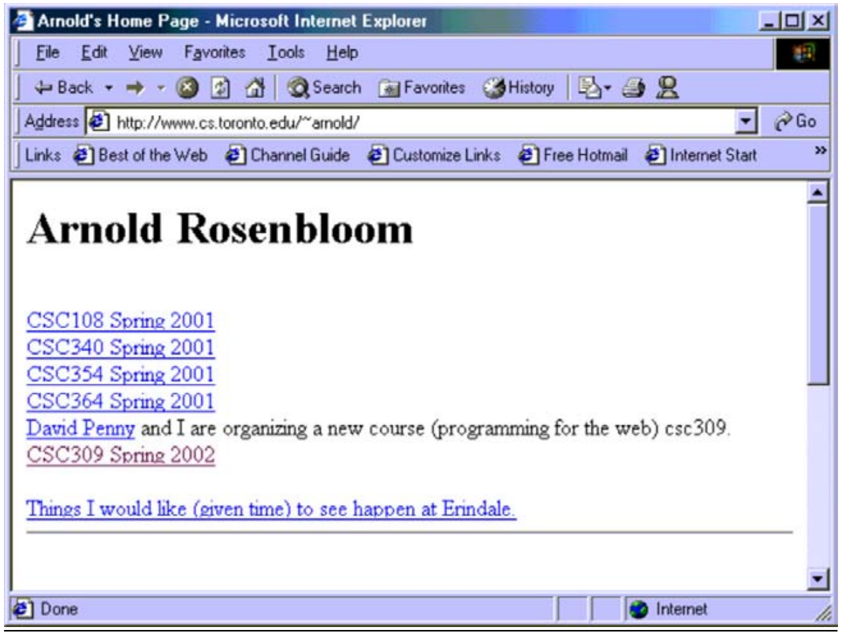
- ***Automatic Learning*** - a design can force learning on the user by offering repetitive patterns of user actions or screen displays.
- Good feature of automatic learning: user actions always involve same number of steps, e.g., select object, select general action to perform on object, select specific case of action.
- Example of non-use of automatic learning: Screens which change standard menu item locations from display to display.
- Bad example of automatic learning: A confirmation action that always requires a carriage return.
- Good example of automatic learning: Confirmations that require some knowledge of context, e.g., the first character of the file to be deleted

Where are the Affordances, Mappings, etc. ?



Where are the Affordances, Mappings,...?




Arnold's Home Page - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites History
Address http://www.cs.toronto.edu/~arnold/
Go
Links Best of the Web Channel Guide Customize Links Free Hotmail Internet Start
Done
Internet

Arnold Rosenbloom

CSC108 Spring 2001
CSC340 Spring 2001
CSC354 Spring 2001
CSC364 Spring 2001
David Penny and I are organizing a new course (programming for the web) csc309.
CSC309 Spring 2002

Things I would like (given time) to see happen at Erindale.

Where are the Affordances, Mappings,...?

- ***Affordances:*** Slider on the right side. Arrows at the top and bottom suggest sliding the bar (even though they are buttons). The size/location of the bar suggests the allowable directions that this can be slid.
- ***Mappings:*** Search button, the icon with the magnifying glass. Magnifying glass used to look for things/expand things.
- ***Feedback:*** The scrolling logo on the top right to indicate that a search for a page is in progress. Tells the user that their last jump to a hyperlink is being processed.
- ***Mental Model:*** Following a sequence of links forms a chain. The UI allows navigation of this chain via the forward and back buttons.
- ***Forcing Functions:*** The forward/back buttons are enabled only if navigation of the chain in the specified direction is allowed.
- ***Automatic Learning:*** Links always consistently highlighted, visited links consistently highlighted. OR, interface uses the Netscape/Explorer layout and functions.

Are We Good Designers?

- Do we put things in the same place in our kitchen and on the same shelf in our refrigerator so that after constant use, we learn exactly where things are through automatic learning?
- Do we organize our clothes in random fashion throughout our closet and our desktop giving no overall mental model of storage?
- Do we post up signs above water faucets and doors indicating that one should turn them right or left or push or pull them - when the original designer of our apartment left no affordances to tell us this?
- Do we constantly bump into things, knock our head, hurt our knees etc.? Do we avoid moving the furniture so that it creates a forcing function that prevents us from walking into something?
- Do we store things with no identification labels that would provide a mapping function to the item we want, e.g., keys on a ring that all look alike?
- Do we respond to email confirming that a time has been set and the message has been received, thus giving feedback to our friends?

Designing User Interfaces: Three Easy Steps

- ***I/O Design:*** Decide who inputs what data when; this may involve
  - ✓ Batch input, such as reading data from a file to update a database at 7pm each day, or
  - ✓ Batch output, such as producing a report every Friday, or
  - ✓ Interactive input and/or output, such as customer access their accounts at the rate of 1,500/hr
- ***Dialogue Design:*** For each input and/or output session design the dialogue structure that will be supported; for example, an ATM session dialogue structure involves user inserting card, system prompting for PIN etc.
- ***Screen Layout and I/O Format Design:*** For each interactive dialogue, design the screens that will be presented to the user (this will depend heavily on the hardware and software platform chosen earlier); for each batch I/O design the format of the input data, or the output report.

User Groups

- In general, an information system will be used by several different groups, including non-technical people (clerks, managers) and technical people (system operators, database administrators, ...)
- Each one of these groups may require its own interface (some assuming no technical background on the user's part, others assuming a lot)
- ***End users*** are the non-technical users of an information system.

User Interface Medium: Monitors

- ***Monitors*** used to display input/output; key characteristics of monitors:
- Display area -- how large is the screen;
- Character sets and graphics -- older monitor technology was character-based (i.e., the monitor could display one of X characters in one of N screen positions, e.g., 60×80); new technology is bitmap-based (i.e., monitor can display a point of different grayscale intensity/colour in one of N screen positions, e.g., 480×640);
- Paging and scrolling -- data are displayed a page-at-a-time, or continuously through scrolling

Windows and Graphical User Interfaces (GUIs)

- Windows provide a user-defined partition of the screen into multiple working areas, much like the documents one may have lying on her desk
- Windows have become an interface standard, with OSF Motif (Unix) Microsoft Windows (IBM PC OS), Apple MacOS (Apple Macintosh OS)
- Graphical user interfaces (GUIs) use icons (graphic symbols), pop-up windows, scroll bars and pull-down menus to offer a user friendly interface
- Other features of GUIs: ***radio buttons***, ***check boxes*** and ***dialogue boxes***
- User friendliness is enhanced by a mouse, trackball, pen or other pointing and input device which reduces the need for a keyboard

Layout Concepts

- The screen is often divided into three boxes
  - ✓ Navigation area (top)
  - ✓ Status area (bottom)
  - ✓ Work area (middle)
- Information can be presented in multiple areas
- Like areas should be grouped together
- Areas and information should minimize user movement from one to another
- Ideally, areas will remain consistent in
  - ✓ Size
  - ✓ Shape
  - ✓ Placement for entering data
  - ✓ Reports presenting retrieved data

Content Awareness and Aesthetics

- All interfaces should have titles.
- Menus should show clearly where you are, also where you came from to get there.
- It should be clear what information is within each area.
- Fields and field labels should be selected carefully.
- Use dates and version numbers to aid system users.
- Interfaces need to be functional and inviting to use.
- Avoid squeezing in too much, particularly for novice users.
- Design text carefully
  - ✓ Be aware of font and size;
  - ✓ Avoid using all capital letters.
- Colors and patterns should be used carefully
  - ✓ Test quality of colors by trying the interface on a black/white monitor;
  - ✓ Use colors to separate or categorize items.

User Experience and Consistency

- How easy is the program to learn?
- How easy is the program to use for the expert?
- Consider adding shortcuts for the expert.
- Where there is low employee turnover, some training can lessen the impact of less precise interfaces.
- ***Consistency*** enables users to predict what will happen and reduces learning curve
- Consistency concerns items within an application and across applications.
- Consistency pertains to many different levels
  - ✓ Navigational controls;
  - ✓ Terminology;
  - ✓ Report and form design.

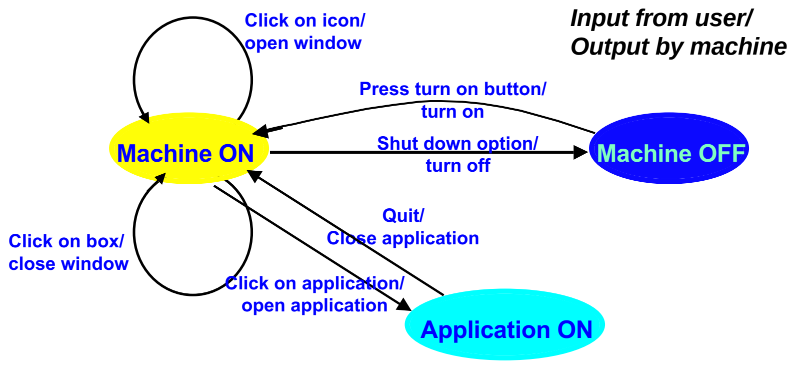
Dialogue Modes

- ***Menu selection*** -- user given a number of options listed on a menu, selects one and the system carries out the option selected or updates its database accordingly, then displays another menu;
  - e.g., macOS and applications, including Powerpoint (used to create these slides)
- ***Instruction sets*** -- dialogue structured around instruction sets which provide the user with a command language (using structured English, mnemonics or free-format syntax
  - e.g., Unix
- ***Question-Answer dialogue*** -- system or user asks questions and gets answers; system-driven (as opposed to user-driven) Q-A easier because it can have built-in structure
- ***Graphic-based dialogue structure*** -- builds on the monitor+mouse capabilities described earlier; uses menus but also many other features

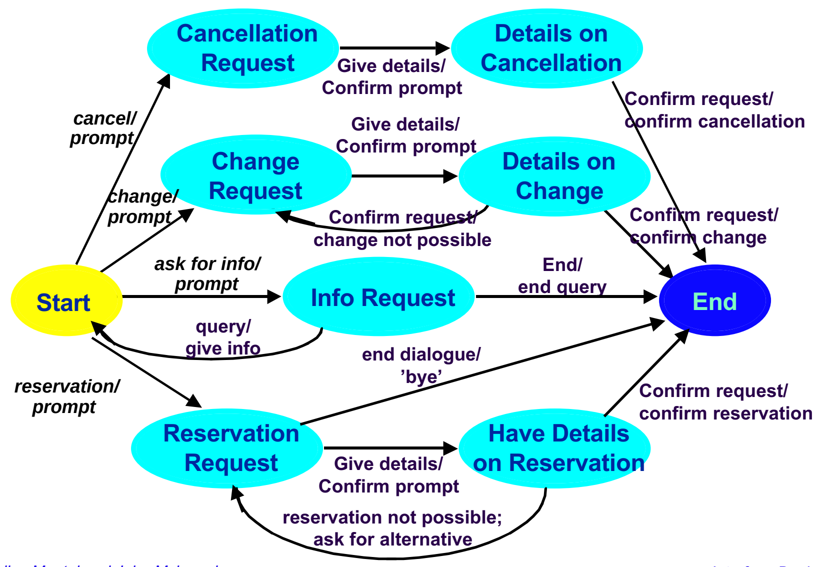
  - ***Graphical User Interfaces clearly the way of the future***

Designing Dialogue Structure

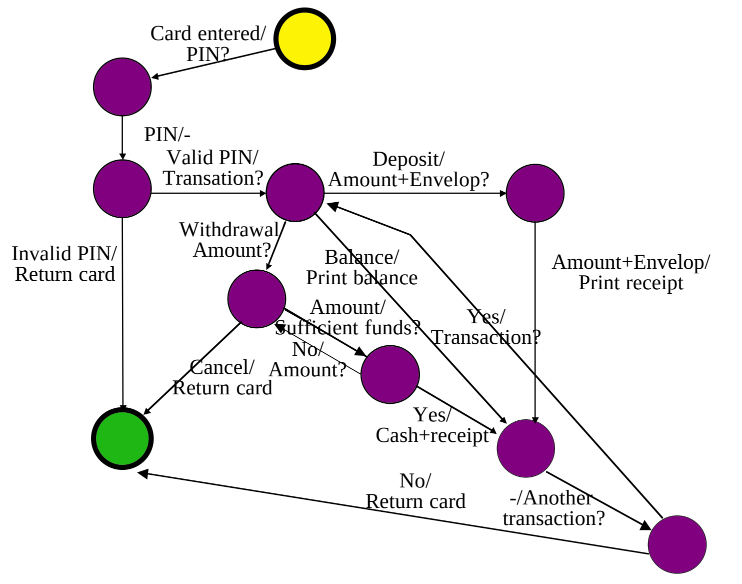
One can use state diagrams to specify dialogue structure to be supported by a user interface. Such diagrams may have only input from the user (“event”), conditions on, and output (“action”) to the user.



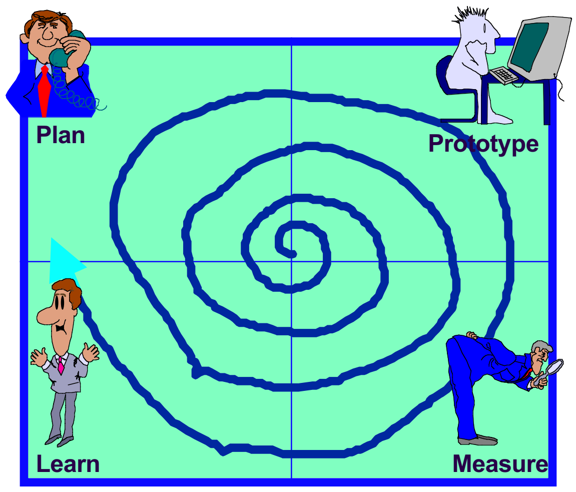
Airline Reservation Dialogue


Cancellation Request
Details on Cancellation
Give details/ Confirm prompt
Confirm request/ confirm cancellation
cancel/ prompt
Change Request
Give details/ Confirm prompt
Details on Change
change/ prompt
Confirm request/ change not possible
Confirm request/ confirm change
Start
ask for info/ prompt
Info Request
End/ end query
End
query/ give info
end dialogue/ 'bye'
reservation/ prompt
Reservation Request
Have Details on Reservation
Confirm request/ confirm reservation
Give details/ Confirm prompt
reservation not possible; ask for alternative

Dialogue Structure for an ATM



How to Design a User Interface: Iterative Design



Iterative Interface Design

Plan -- identify what needs to be learned; do highest risk items first, identify why they are high risks; identify user(s), tasks to be performed through the interface, time allowed to do iteration
e.g., temporary secretary, type letters, 1hr

Prototype -- prototype only the pieces that are needed; intended to minimize effort and maximize feedback

Measure -- gather data on how effective the prototype is; look for false affordances, missing affordances, useful affordances; also check for overhead in learning the interfaces as opposed to doing useful work

Learn -- evaluate the data to identify areas that need further elaboration

User must be in the loop of the iterative design process!

Prototyping

- Build a "quick-and-dirty" implementation of the interface in a very high level language (Lisp, Prolog, 4GL) or GUI tools, just to show the user what the interface looks like
- Do a ***paper mock-up*** using cardboard, index cards, colour markers, tape, scissors,...
  - Use cardboard rectangles or flip charts to represent the screen; use index cards for drop down menus;
  - Avoid technical terms, "very intelligent" help, un-implementable features.

Paper Mock-Ups

- Designer plays "the computer", write on tape or transparency computer's response
- Users use their fingers as a mouse
- Users write "typed" input on removable tape or transparency
- Mock-ups take away the intimidation of the "technology barrier", make users feel at ease; users' imagination fills the gaps
- Mock-ups can be changed very quickly (quick feedback important to users)
- However, mock-ups only approximate look-and-feel of interface, can't be used to assess response times

Do users and organizations accept mock-ups?
Yes, they do!

Other Input/Output Design

- Apart from user interfaces, through which the users input/output directly information into/out of an information system, other input or output modes may have to be designed as well.
- For example, a government information system may require a data entry interface, where staff input data read in from forms filled out by people (because government can't assume that everyone has and can use a computer)
- Or, an output report format may be designed for bank executives who don't have the time to learn to use a particular system, but do want to keep track of certain statistics.
- Below we list some of the options in designing such I/O interfaces.

Output Design: Types of Outputs

- ***External outputs*** -- leave the system permanently
  e.g., paycheques, airline tickets, boarding passes,...

- ***Turnaround outputs*** -- leave and later re-enter the system
  e.g., invoices, purchase orders

- ***Internal outputs*** -- never leave the system (useful for monitoring and management purposes)
  e.g., internal reports, summary reports etc., used for system administration

Input Design

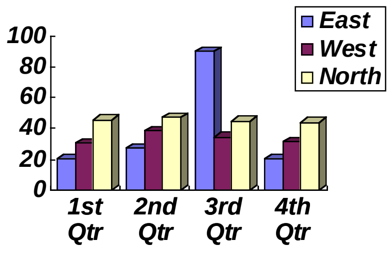
- **Data capture** involves the identification of new data to be inserted in an information system, e.g., a photo
- *Data entry* is the process of translating the source document into a machine readable form
  - e.g., digitizing the photo
- *Data input* is the actual entry of data (already in machine-readable form) into the computer

Input/Output Media and Formats

- An input/output ***medium*** is the material used to record information
  - e.g., punched cards, tape, diskette, paper or video display device
- An input/output ***format*** determines the way information is organized on the medium
  - – e.g., for output, tables, bar or pie charts,...

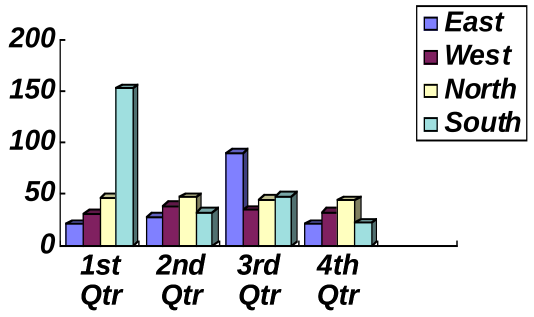
Output

- *Output media* -- paper used most frequently, but also microfiche (good for archiving), video (fast-growing use)
- **Output formats** -- ***tabular*** format, ***zoned*** or form-based format places text or numbers in designated areas, ***graphic*** format uses graphs or charts to display information, *narrative* format uses narrative form to present information



Preparing Graphs and Charts

	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
East	20.4	27.4	90	20.4
West	30.6	38.6	34.6	31.6
North	45.9	46.9	45	43.9
South	153.1	32.6	47.9	22.1



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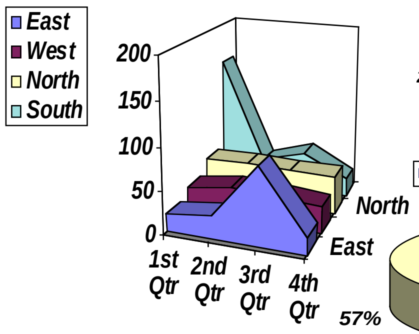
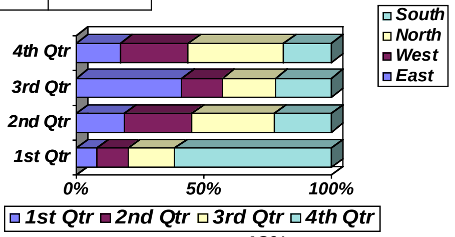
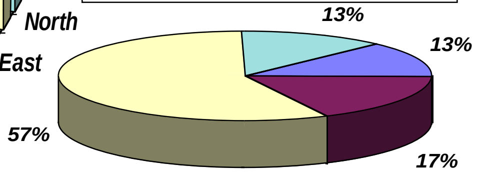






Internal Controls for I/O

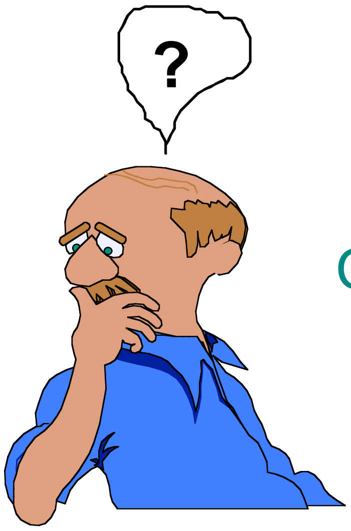
- ***Monitor number of inputs*** -- keep track of batch#, # of documents, # of lines; these can be compared with outputs
- ***Data validation for inputs*** -- this involves programs which check for typos, missing or suspicious information

Data errors can be reduced dramatically because of data validation procedures

- Internal controls for outputs include specifying exactly the time, volume and destination of each output, also access controls (e.g., password)

Summary

- The acceptance of an information system by its users depends critically on its user interfaces
- User interfaces are best developed through prototyping, involving prototype implementations or paper mock-ups
- In designing a user interface, one needs to keep in mind cognitive principles about human information processing, and memory organization
- Human-Computer Interaction is the area of Computer Science which studies such principles and offers ways they can be exploited to build better user interfaces



Questions?

Additional Reading

[Norman88] Norman, D., *The Psychology of Everyday Things*, Basic Books, 1988.

[Shneiderman92] Shneiderman, B., *Designing the User Interface: Strategies for Effective Human-Computer Interaction*, Addison-Wesley, 1992.