Vorlesung
Mensch-Maschine-Interaktion

Albrecht Schmidt
Embedded Interaction Research Group
LFE Medieninformatik
Ludwig-Maximilians-Universität München
http://www.hcilab.org/albrecht/

Chapter 2
Basics of HCI and History

- 2.1 Motivation
- 2.2 Principles for UI-Design
- 2.3 Understanding Errors
- **2.4 Consistency**
- 2.5 Basic Models
- 2.6 A Brief History of HCI

Consistency (1)

- Consistency
  …be systematic
  - lexical
  - syntactic
  - semantic levels
- Why consistency?
  - Makes things easier to remember,
  - aids in generalizability,
  - Helps reduce potential for error
- Modeling approach
  - Grammars, e.g. BNF
- Consistent
  - Delete/insert character
  - Delete/insert word
  - Delete/insert line
  - Delete/insert paragraph
- Inconsistent – variant 1
  - Delete/insert character
  - Delete/insert word
  - Remove/insert line
  - Delete/insert paragraph
- Inconsistent - variant 2
  - Take-away/insert character
  - Delete/add word
  - remove/put-in line
  - eliminate/create paragraph
- Inconsistent - variant 3
  - Character deletion/insertion
  - Delete/insert word
  - Line deletion/insertion
  - Delete/insert paragraph

Consistency (2)

- Lexical Consistency
  - Coding consistent with common usage, e.g.
    - red = bad, green = good
    - left = less, right = more
  - Consistent abbreviation rules
  - equal length or first set of unambiguous chars.
  - Devices used same way in all phases
  - character delete key is always the same
- Syntactic Consistency
  - Error messages placed at same (logical) place
  - Always give command first - or last
  - Apply selection consistently, e.g. select text then apply tool or select tool and then apply to a text
  - Menu items always at same place in menu (muscle memory)

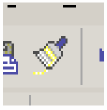
Consistency (3)

- Semantic Consistency
- Global commands always available
  - Help
  - Abort (command underway)
  - Undo (completed command)
- Operations valid on all reasonable objects
  - if object of class "X" can be deleted, so can object of class "Y"
- Applicability
  - to command line user interfaces
  - Keyboard short cuts
  - Speech interfaces
  - Tool bars
  - Menus
  - Selection operation
  - Gestures

Consistency through Grammars

- Example – Task-Action-Grammer (TAG)
  - Task[direction,unit]→symbol[direction]+letter[unit]
  - Symbol[direction=forward]→"CTRL"
  - Symbol[direction=backward]→"ALT"
  - Letter[unit=word]→"W"
  - Letter[unit=paragraph]→"P"
- Example - Commands
  - Move cursor on word forward: CTRL-W
  - Move cursor on word backward: ALT-W
  - Move cursor on paragraph forward: CTRL-P
  - Move cursor on paragraph forward: ALT-P

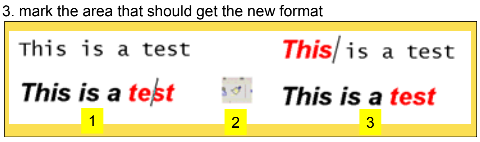
How does the Format Brush work?



- compare it to bold, italic, underline, …

Consistency in GUIs

- Format Brush
  1. place the cursor in the format you want to use
  2. switch the format brush on
  3. mark the area that should get the new format



- Bold face font (1)
  1. Mark the text that should become bold
  2. Click the toolbar button for bold
- Bold face font (2)
  1. Switch bold face font on (Click the toolbar button for bold)
  2. Write text
  3. Switch it of when ready

Inconsistency

- Dragging file operations?
  - folder on same disk vs. folder on different disk
  - file to trashcan vs. disk to trashcan
- Sometimes inconsistency is wanted
  - E.g. Getting attention for a dangerous operation
  - Use inconsistency very carefully!
- Inconsistency at one level may be consistent at another
  - moving icon to file cabinet, mailbox, or trash causes icon to disappear (Xerox Star)
  - choices for when dragging file icon to printer icon:
    - delete the icon (and thus the file)
    - disappears "in" the printer from where it can be retrieved
    - return icon to original location

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Models & Theories

- What are models and theories used for?
  - explanatory
  - **predictive**
  - descriptive/taxonomy
- Models on different levels
  - concept
  - human action
  - …
  - dialog
  - keystroke
- What is modelled?
  - user
  - task
  - dialogs
  - transitions
  - software
  - input/output
  - system
  - interaction
  - behaviour
  - …
  - combination of these

Example Motivation - Prediction

http://www.xe.com/ucc/

- Convert 712 GBP into EUR
- Hand is on the mouse to start with
- How long will it take?

Plans and Situated Actions Distributed Cognition

- complex interaction between people
- interaction with different devices
- interaction with information in different forms
- complex interaction with the physical environment
- Interruptions as standard phenomenon of live
- Computer usage can not be seen isolated from that

- Suchman, 1990
  - human plans are often not orderly executed
  - plans are often adapted or changed
  - user's actions are situated in time and place
  - user's actions are responsive to the environment
  - distributed cognition – knowledge is not just in the user's head it is in the environment

This questions many of the modeling approaches…

Background: The Psychology of Everyday Action (Norman 2002, Chapter 2)

- People are blaming themselves for problems caused by design
  - If the system crashes and the user did everything as he is supposed to do the developer/system is blamed
  - If the system crashes and the user operated the system wrongly the user is blamed

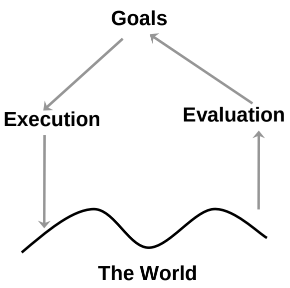
- People have misconceptions about their actions
  - The model must not be fully correct – it must explain the phenomenon

- People try to explain actions and results
  - Random coincidence may lead to assumptions about causality

Action Cycle

- The action is goal directed
  - What do we want to happen?
  - What is the desired state?

- Human action has two major aspects
  - Execution: what we do to the world
  - Evaluation: compare if what happens is what we want



Action Cycle Stages of Execution

- Goal

  translated into
- An intention to act as to achieve the goal

  translated into
- The actual sequence of actions that we plan to do

  translated into
- The physical execution of the action sequence

Action Cycle Stages of Evaluation

- Perceiving the state of the worlds

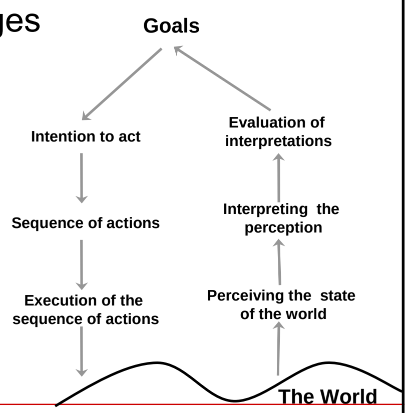
  followed by
- Interpreting the perception according to our expectations

  followed by
- Evaluation of the interpretations with what we expected to happen (original intentions)

  followed by
- Goal

Seven Stages of Action

1. Forming a goal
2. Forming an intention
3. Specifying an action
4. Executing the action
5. Perceiving the system state
6. Interpreting the system state
7. Evaluating the outcome



Gulf of Execution

- The difference between the intentions and the allowable actions is the Gulf of Execution
  - How directly can the actions be accomplished?
  - Do the actions that can be taken in the system match the actions intended by the person?
- Example in GUI
  - The user wants a document written on the system in paper (the goal)
  - What actions are permitted by the system to achieve this goal?
- Good design minimizes the Gulf of Execution

Gulf of Evaluation

- The Gulf of Evaluation reflects the amount of effort needed to interpret the state of the system how well this can be compared to the intentions
  - Is the information about state of the system easily accessible?
  - Is it represented to ease matching with intensions?
- Example in GUI
  - The user wants a document written on the system in paper (the goal)
  - Is process observable? Are intermediate steps visible?
- Good design minimizes the Gulf of Evaluation

Implications on Design

- Principles of good design (Norman)
  - Stage and action alternatives should be always visible
  - Good conceptual model with a consistent system image
  - Interface should include good mappings that show the relationship between stages
  - Continuous feedback to the user
- Critical points/failures
  - Inadequate goal formed by the user
  - User does not find the correct interface / interaction object
  - User many not be able to specify / execute the desired action
  - Inappropriate / mismatching feedback

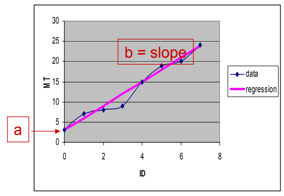
Fitts' Law
Predicting Movement Time (MT)

- *MT = a + b* log2(2*A / W*)
  - A=amplitude
  - W=width
  - a, b constants dependent on the input device
  - Fitts' law predicts that the time to acquire a target is logarithmically related to the distance over the target size.
  - Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. *Journal of Experimental Psychology, 47*, 381-391.
- *MT = a + b* log2(*A / W* + 1)
  - improvement of the original fitts' law
  - MacKenzie, I. S. (1989). A note on the information-theoretic basis for Fitts' law. *Journal of Motor Behavior*, *21*, 323-330.

http://www.billbuxton.com/fitts91.html

Fitts' Law – index of difficulty

- How difficult the motor pointing task is
- ID=Index of Difficulty
- ID=log2(A/W + 1)
- ID has the unit bits
- *MT = a + b* ID
- a has the unit s
- b has the unit s/bits
- Collect data set and calculate a and b
- a can be negative



linear regression model

Fitts' law in practice

- MT = a + b log2((A/W) + 1)
- A = distance from starting position
- W = size of target along line of motion (for a 2-D target use smaller of height or depth)
- Common values a=50ms, b=150ms/bit
- Jef Raskin, The Humane Interface, ACM Press 2000, p93-94

Experimental data for pointing devices
MT = *a* + *b ID*, where *ID* = log2(*A/W* + 1).

Regression Coefficients

Device	r^a	Intercept, *a* (ms)	Slope, *b* (ms/bit)	*IP* (bits/s)[b]
*** Pointing ***				
Mouse	.990	-107	223	4.5
Tablet	.988	-55	204	4.9
Trackball	.981	75	300	3.3
*** Dragging ***				
Mouse	.992	135	249	4.0
Tablet	.992	-27	276	3.6
Trackball	.923	-349	688	1.5

[a] $n = 16$, $p < .001$
[b] *IP* (index of performance) = 1/*b*

- From http://www.billbuxton.com/fitts91.html
  MacKenzie, I. S., Sellen, A., & Buxton, W. (1991). A comparison of input devices in elemental pointing and dragging tasks. *Proceedings of the CHI `91 Conference on Human Factors in Computing Systems*, pp. 161-166. New York: ACM.

Hick's Law

- The time needed to make a selection is proportional to the log number of alternatives given
- H is the information-theoretic entropy of a decision
- T = b H
- n alternatives of equal probability
  H = log2(n + 1).
- Alternatives of unequal probability
  pi = the probability of alternative i
  H = Σ pi log2(1/pi + 1).
- Common practical values: b=150 ms/bit
- http://www.usabilityfirst.com

Hick's law does not apply if it requires linear search (e.g. a randomly ordered list of commands in a menu). It applies if the user can search by sub-division

Object-Action Interface Model (OAI)

- Targeted at GUIs and applications in real world domains
- Steps
  1. Understanding the task, including
     - Universe of the real world, objects, atoms
     - Actions user can apply to objects, intention to steps
  2. Create a metamorphic representation of interface objects and actions
     - Object representation – metaphor to pixel
     - Actions – from plan level to specific clicks

http://www.cs.umd.edu/class/fall2002/cmsc838s/tichi/oai.html

GOMS
Goals, Operators, Methods, Selection Rules

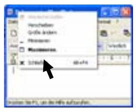
- GOMS techniques produce quantitative and qualitative predictions of how people will use a proposed system
- Different models proposed
- Basics:
  - Goals – goal a user wants to accomplish (in real scenarios hierarchical)
  - Operators – operation (at a basic level) that are used to achieve a goal
  - Methods – sequence of operators to achieve a goal
  - Selection Rules – selection of method for solving a goal (if alternatives are given)

- John, B. & Kieras, D. (1996). Using GOMS for user interface design and evaluation: which technique? *ACM Transactions on Computer-Human Interaction, 3,* 287-319.

Example (adapted from Dix 2004, p. 423):
Close the window that has the focus (Windows XP)

- Compare three options:

ALT + F4 Key-shortcut



Context-menu

Close-button

GOAL: CLOSE-WINDOW
. [select GOAL: USE-KEY-SHORTCUT
. . hold-ALT-key
. . press-F4-key
. GOAL: USE-CONTEX-MENU
. . Move-mouse-win-head
. . Open-menu (right click)
. . Left-click-close
. GOAL: USE-CLOSE-BUTTON
. . Move-mouse-button
. . Left-click-button]

Rule 1: USE-CLOSE-BUTTON method if no other rule is given
Rule 2: USE-KEY-SHORTCUT method if no mouse is present

Example (adapted from Dix 2004, p. 424):
copy a journal article

GOAL: PHOTOCOPY-PAPER
. GOAL: LOCATE-ARTICLE
. GOAL: COPY-PAGE repeat until no more pages
. GOAL: ORIENT-PAGE
. . OPEN-COVER
. . SELECT-PAGE
. . POSITION-PAGE
. . CLOSE-COVER
. GOAL: PRESS-COPY
. GOAL: VERIFY-COPY
. . LOCATE OUTPUT
. . EXAMINE COPY
. GOAL: COLLECT-COPY
. . LOCATE OUTPUT
. . REMOVE-COPY
(outer goal satisfied!)
. GOAL: RETRIEVE-ORIGINAL
. . OPEN-COVER
. . TAKE-ORIGINAL
. . CLOSE-COVER

Likely that the users forget this

Example (adapted from Dix 2004, p. 430):

Example of a Cash-Machine
Why you need to get your card before the money.

- Design to lose your card..

GOAL: GET-MONEY
. GOAL: USE-CASH-MACHINE
. . INSERT-CARD
. . ENTER-PIN
. . SELECT-GET-CASH
. . ENTER-AMOUNT
. . COLLECT-MONEY
(outer goal satisfied!)
. . COLLECT-CARD

- Design to keep your card..

GOAL: GET-MONEY
. GOAL: USE-CASH-MACHINE
. . INSERT-CARD
. . ENTER-PIN
. . SELECT-GET-CASH
. . ENTER-AMOUNT
. . COLLECT-CARD
. . COLLECT-MONEY
(outer goal satisfied!)

GOMS - Example

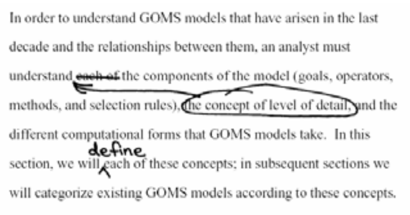

In order to understand GOMS models that have arisen in the last decade and the relationships between them, an analyst must understand ~~each of~~ the components of the model (goals, operators, methods, and selection rules), the concept of level of detail, and the different computational forms that GOMS models take. In this section, we will define each of these concepts; in subsequent sections we will categorize existing GOMS models according to these concepts.

Figure 1. The example task: editing a marked-up manuscript.

- From: John, Bonnie and Kieras, David E., The GOMS Family of User Interface Analysis Techniques: Comparison and Contrast, *ACM Transactions on Computer-Human Interaction 3,4* (December 1996b), 320-351

Keystroke-Level Model (KLM)

- simplified Analysis
- only operators on keystroke-level
- no goals, no methods, no selection rules
- list of basic operators to do a task
  - keystrokes or button presses (K),
  - pointing with the mouse to a target (P),
  - hand movement between mouse an keyboard (H)
  - mental operators (M) – placed by heuristics
  - Drawing (D)
  - System response (R)

- Card, S. K., Moran, T. P., and Newell, A. 1980. The keystroke-level model for user performance time with interactive systems. *Commun. ACM* 23, 7 (Jul. 1980), 396-410.

Times for basic operators

Operator	Description and Remarks	Time (sec)
K	Keystroke or button press. Pressing the SHIFT or CONTROL key counts as a separate K operation. Time varies with the typing skill of the user; the following shows the range of typical values:	
	Best typist (135 wpm)	.08[a]
	Good typist (90 wpm)	.12[a]
	Average skilled typist (55 wpm)	.20[a]
	Average non-secretary typist (40 wpm)	.28[b]
	Typing random letters	.50[a]
	Typing complex codes	.75[a]
	Worst typist (unfamiliar with keyboard)	1.20[a]
P	Pointing to a target on a display with a mouse. The time to point varies with distance and target size according to Fitts's Law. The time ranges from .8 to 1.5 sec, with 1.1 being an average time. This operator does not include the button press that often follows (.2 sec).	1.10[c]
H	Homing the hand(s) on the keyboard or other device.	.40[d]
$D(n_D, l_D)$	Drawing (manually) n_D straight-line segments having a total length of l_D cm. This is a very restricted operator; it assumes that drawing is done with the mouse on a system that constrains all lines to fall on a square .56 cm grid. Users vary in their drawing skill; the time given is an average value.	$.9n_D + .16l_D$[e]
M	Mentally preparing for executing physical actions.	1.35[f]
R(t)	Response of t sec by the system.	t

- Experimentally measured
- From: Card, S. K., Moran, T. P., and Newell, A. 1980. The keystroke-level model for user performance time with interactive systems. *Commun. ACM* 23, 7 (Jul. 1980), 396-410.

Basic time estimation

Operator	Remarks	Time(sec)
K	Press Key	
	good typist(90wpm)	0.12
	poor typist(40wpm)	0.28
	non-typist	1.20
B	Mouse button press	
	down or up	0.10
	click	0.20
P	Point with mouse	
	Fitts's law	0.1lg(D/S +0.5)
	Average movement	1.10
H	Home hands to and from keyboard	0.40
D	Drawing- domain-dependent	__
M	Mentally prepare	1.35
R	Response from sytem - measure	__

- http://www.cc.gatech.edu/classes/cs6751_97_winter/Topics/user-model/
  Dix et al. page: 438

Calculate overall time required

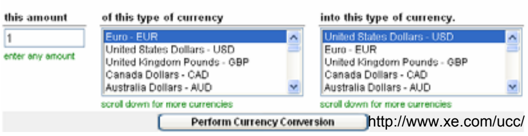
- $T_{task} = T_{acquire} + T_{execute}$
- $T_{execute} = T_K + T_B + T_P + T_H + T_D + T_M + T_R$
  - T_K = time for key presses
  - T_B = time for button presses / clicks
  - T_P = time for pointing
  - T_H = time moving hand between mouse and keyboard
  - T_D = time for drawing
  - T_M = time for mentally preparing
  - T_R = time for system response

Example

- Start the command shell in windows
- What to do?
  - Click 'Start'
  - Click 'Execute'
  - Think of command
  - Type 'cmd'
  - hit 'return key'
- KLM
  - P[to start] 1,10s
  - B[left click] 0,20s
  - P[to execute] 1,10s
  - B[left click] 0,20s
  - H 0,40s
  - M 1,35s
  - K[c] 0,28s
  - K[m] 0,28s
  - K[d] 0,28s
  - K[return] 0,28s

  5,47s
- T = 2*P+2*B+4*K+H+M

KLM - Example



http://www.xe.com/ucc/

- Convert 712 GBP into EUR
- Hand is on the mouse to start with

KLM – Example result

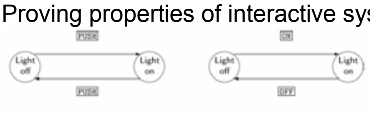
- P[to input field]
- B[click]
- H[to keyboard]
- M[consider number]
- 4K[BSP-7-1-2]
- H[to mouse]
- M[consider currency]
- P[to GBP]
- B[click]
- M[consider currency]
- P[to EUR]
- B[click]
- P[to convert]
- B[click]
- R[show page with result]

- 4*P = 4,40s
- 4*B = 0,80s
- 2*H = 0,80s
- 3*M = 4,05s
- 4*K = 1,12s
- 1*R = 1,00s
- Summe= 12,17s

Further reading
User Interface Design With Matrix Algebra
Harold Thimbleby

ACM Transactions on Computer-Human Interaction, Vol. 11, No. 2, June 2004, Pages 181–236.

- Algebra analysis of interactive systems
- Proving properties of interactive systems



a. Light with push-on/push-off action. b. Light with separate on/off actions.

Finite state machines (FSMs)

<u>States as vectors</u>:
on (1 0)
off (0 1)

<u>Actions as Matrix</u>:

$$\boxed{\text{PUSH}} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$$

<u>Press the button when off results in on</u>

$$\textbf{off}\,\boxed{\text{PUSH}} = (0\ 1)\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} = (1\ 0) = \textbf{on}$$

<u>Press the button twice does not alter the state</u>

$$\boxed{\text{PUSH}}\,\boxed{\text{PUSH}} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} = I$$

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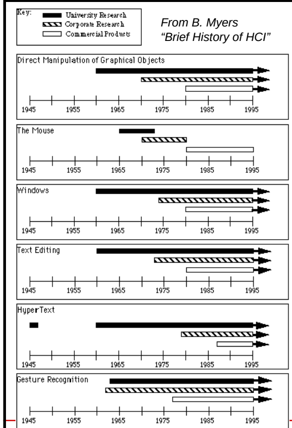
Evolution of HCI 'interfaces'

- **50s** - Interface at the hardware level for engineers - switch panels
- **60-70s** - interface at the programming level - COBOL, FORTRAN
- **70-90s** - Interface at the terminal level - command languages
- **80s** - Interface at the interaction dialogue level - GUIs, multimedia
- **90s** - Interface at the work setting - networked systems, groupware
- **00s** - Interface becomes pervasive
  - RF tags, Bluetooth technology, mobile devices, consumer electronics, interactive screens, embedded technology

Student Project

http://www.hcilab.org/projects/historybook/



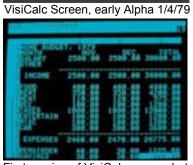
From B. Myers "Brief History of HCI"

A Brief History of HCI

- Early machines used batch processing (e.g. punch card machines)
- Terminals with command line interfaces
- Graphical user interfaces with pointing device
- Multimodal user interfaces

VisiCalc - Widespread use of an Interactive Application

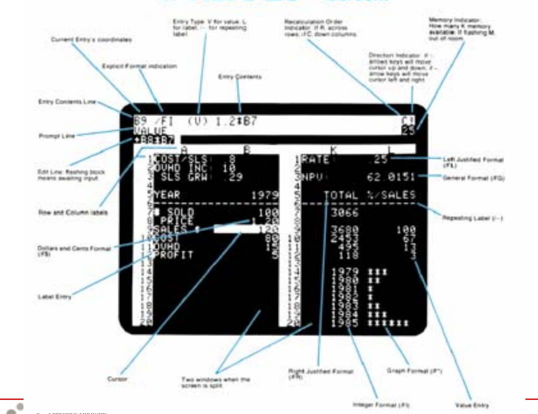
VisiCalc Screen, early Alpha 1/4/79



First version of VisiCalc screenshot

- Instantly calculating electronic spreadsheet
- Early killer app for PCs
- Significant value to non-technical users

A VISICALC™ Screen:



Changing Interaction Paradigms

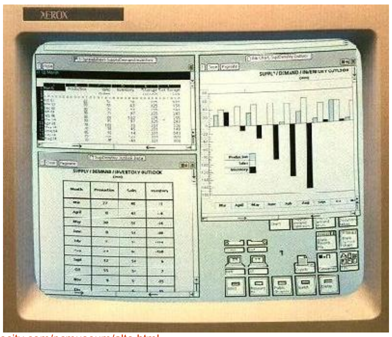
- Replacement of command-language
- Direct manipulation of the objects of interest
- Continuous visibility of objects and actions of interest
- Graphical metaphors (desktop, trash can)
- Windows, icons, menus and pointers
- Rapid, reversible, incremental actions

- Origins of direct manipulation an graphical user interfaces
  - Ivan Sutherland's Sketchpad, 1963, object manipulation with a light pen (grabbing, moving, resizing)
  - Douglas C. Engelbart, 1968, Mouse, NLS
  - XEROX ALTO (50 units at Universities in 1978)
  - XEROX Star (1981)
  - Apple Macintosh (1984)

XEROX ALTO

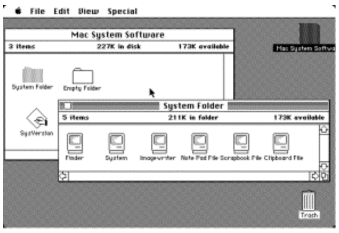
Photos from http://members.fortunecity.com/pcmuseum/alto.html

XEROX Star



Photos from http://members.fortunecity.com/pcmuseum/alto.html

Apple Macintosh



1984 – commercially successful GUI

More GUIs

Amiga 1985

NextStep 1989

Win 3.11 1992

OS/2 1992

Lessons Learned from History

- Technology drives new user interface concepts and interaction metaphors
- New user interfaces create new applications
- Designs and user interface concepts evolve
- You can not hide the user interface - good ideas spread out
- The first to come out with a new user interface is not necessarily the most successful

- Technologies to look out for?
  - Eye gaze detection
  - Speech and gesture recognition
  - EEG, ECG, EMG interfaces (e.g. http://www.biosemi.com/products.htm) ElectroEncephaloGraphy, ElectroCardioGraphy, ElectroMyoGraphy

Brain Ball

http://smart.tii.se/smart/projects/brainball/index_en.html

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