Notes of CZ2004 Human Computer Interaction

MoeKid101

1 Introduction

Human Computer Interaction is often human input and computer output, counterexample being CAPTCHA. The discipline is about *design*, *evaluation* and *implementation* of interactive computer systems for human use. The people contributing: computer scientists, psychologists, software engineer, ergonomists, sociologists, *e.t.c*, of which **technical writers** (those writing user manuals) are important.

Why study HCI: HCI or UI design is major part but difficult because developers aren't users, and there is no silver bullet.

User Population Distribution: Users include power user, computer literate and the others, and concentration should be put on the others.

Features vs. Design: Design is different from providing more features (cake vs. its ingredients), instead it's providing right features. Simplicity is important.

> *e.g.* Google: provide the best user experience possible, specified as "clear and simple interface" and "instant loading of pages".

Design for People: User, corporate and programmer have different goals, satisfy users' goals. Users' goals can be divided into **daily-use** (most often, main goals), **necessary-use** (not as frequent) and **edge-case** (rarely used but essential) scenarios. Find out users' goals using surveys.

2 Usability

Three aspects: **effective**, **efficient** and **satisfactory**.

Goals for *Usability Requirements*:

(1) Ascertain user's needs: Find what tasks must be done (all three scenarios). Functionality must match, neiter excessive nor inadequate.

(2) Ensure reliability: Make user actions function as specified, data reflect database value, and system available as often as possible. User's trust is fragile.

(3): **Standardization** Use existing standards to aid learning and avoid errors (*e.g.* virtual calcs must look like real calcs).

Integration Cooperate well with other softwares to reduce users' workload.

Consistency use similar action sequences and visual presentations in similar situations (*e.g.* windows menus).

Portability Let the product run across different platforms.

(4) Complete on time and within budget.

Meausres of usability: Five human factors focused on effectiveness, efficiency and satisfaction. Measure by user studies.

(1) Time to learn: efficiency, on new users instead of experts.

(2) Speed of performance: efficiency, need a benchmark e.g. competitor. But maybe there isn't benchmark.

(3) Rate of errors by users: effectiveness.

(4) Retention over time: effectiveness.

(5) Subjective satisfaction: satisfaction.

Application types: (different types have different preference over different measures)

(1) Life-critical: Reliability matters. Error-free performance is desired, but training time, cost and user satisfaction aren't important because all users are well-trained professionals.

(2) Industrial and Commercial: Banking, insurance and billing system. Requires ease of learning, speed of performance and error rates because they are related to costs. Subjective satisfaction is also important to reduce operator burnout.

(3) Home, Office and Entertainment: Word processing, email, games, search engines. Requires ease of learning, low error rates and subjective satisfaction. Involves various types of users (novice, experts) so choosing functionality is hard, *layered structure* is often chosen.

(4) Exploratory, Creative and Collaborative: Artist toolkits, software development, music composition (supporting human creativity). Users might have no CS knowledge, so make UI vanish from users' tasks.

(5) Sociotechnical: Often government systems including voting, health support, identity verification. Need trust, privacy and security. Feedback is important to build trust and ease of learning matters because most users are novices.

Universal Usability: make interfaces as usable and enjoyable by everyone. Not always possible, so multiple interfaces might be needed. Seven topics to look at:

(1) Physical Ability and Workplace.

(2) Cognitive and Perceptual Abilities.

(3) Personality Differences: *e.g.* MBTI.

(4) Cultural and International Diversity: left-to-right vs. right-to-left, different date and time formats, different measure systems

(*e.g.* kg vs. pound). Therefore, usability studies should be done with users from different countries.
(5) Users with Disabilities: Should plan early. ***Temporary Disability***: *e.g.* driving users can't read, hearing impossible in noisy environment.
(6) Considerations for Elderly: Reduced motor skills, perception, sensing, speed and memory.
(7) Considerations for Children: Small targets and mouse-dragging mightn't be used; instructions aren't effective; complex sentences must be avoided. Must ensure safety, easy to reset.

3 Guidelines, Principles and Theories

Guidelines: specific, practical and narrow, often specific to each company (those which designers in each company must stick to).
Principles: mid-level, widely applicable. We start from this.
Theories: high-level, tested, proven and broadly useful. Describing objects and actions to support education and communication.

3.1 Guidelines

Initiate from experience, but gradually become shared document as companies grow. Composed of rules, examples, and documents. ***Pros***: built upon experience, and allows for continued improvements. ***Cons***: Too specific and hard to innovate. Might be unrealistic and hard to apply.

3.2 Principles

Eight Golden Rules:
(1) Strive for consistency. Create consistent sequence of actions for similar situations, use identical terminology and consistent visual layout (*e.g.* fonts, color).
(2) Cater to universal usability. Analyze needs of various user groups. ***Plasticity***: content used on any type of display.
(3) Offer informative feedback. *e.g.* progress bar. Be modest for common tasks and provide substantial feedback for errors and uncommon tasks.
(4) Design dialogs to yield closure. All actions are organized into beginning, middle and ending. Make users know the progress. The ending dialog leads to sense of accomplishment.
(5) Permit easy reversal of actions. Properly design ***UNDO*** and let users know they can undo.
(6) Support internal locus of control. Always make user feel in control. ***Causality***: no action unless user involved.
(7) Reduce short-term memory load. Humans only remember 7 ± 2 items of information. Always keep display simple. *e.g.* Apple only allows 4 apps to be in bottom of screen.
(8) Prevent errors. Gray out menus that don't apply. Always provide instructions when errors occur and don't change system state. Error messages should help fix error and reduce similar errors. Be specific and positive.

Step 1: Determine user's skill levels. Start with population profile (age, education, culture, training, *e.t.c*). Catering to different needs from different skill levels, use ***layered strategy***.
Novice: restrict vocabulary, provide help, restrict number of actions and provide feedback.
Knowledgeable Intermittent Users: they understand task concepts but may not remember all features needed. Provide consistent sequences of actions, meaningful feedback and guides to frequent patterns. ***UNDO*** needed to protect from danger.
Experts: the only goal is efficiency. Need rapid response time, brief feedback and various accelerator like shortcuts or macros.

Step 2: Task analysis. Done through observing and interviewing users. Break high-level tasks down. Prioritize the performance of high-frequency tasks.

Step 3: Choose interaction style.
(1) Direct Manipulation: directly manipulate visual representations like icons. ***Pros***: fast, providing in-time feedback, easy to learn, so good for novices. ***Cons***: hard to program.
(2) Menu Selection: ***Pros***: clear structure. ***Cons***: hard to make actions understandable.
(3) Form Fill-in: user enter data. ***Pros***: rapid. ***Cons***: formatting required, must be able to respond to errors, and training is required, only suitable to intermittent and expert users.
(4) Command Language: only for expert users. ***Pros***: feeling of control, rapid and flexible. ***Cons***: high error rates and hard to create error messages, so training required.
(5) Natrual Language: the ultimate goal, computers directly respond to natural language. Still in research.

3.3 Theories

Stage of Actions Model: goals are formed first, then people take actions, finally people check their goals. Therefore two primary aspects: execution and evaluation.
Seven stages: (1) forming the goal, (2) forming the intention, (3) specifying the action, (4) executing the action, (5) perceiving the state, (6) interpreting the state, (7) evaluating the outcome.
Gulf of execution: user wants to do something but no action allowed.
Gulf of evaluation: user expects something but system's representation is different.

4 Prototyping and Evaluating

Three pillars in the past: guidelines and documents, UI software tools and expert reviews. But now there is an extra: ***UI requirement analysis*** done through ethnographic observation. The key is

involving the users through talking to users or interviewing them in their workplace. Designers should explain designs, better with visuals or demos, leading to the importance of **prototypes**.
Ethnographic observation: (meaning study of folks/people) get to know users through long-term observation, either participatory or non-participatory. Steps include:

(1) Preparation: understand policies, culture, system and history. Prepare questions and get permission to interview.
(2) During study: establish rapport with managers and targetted users. Observe and follow the emerging clues.
(3) Analysis: compile and interpret the data.
(4) Reporting: consider multiple audiences and present the findings.

Participatory design: actively involve users. They cooperate with designers during innovation, helping define the problem and evaluating proposed solutions. Designers design how to design, but during designs, users are 1st class.

Pros: accurate task analysis, more opportunity of user influence (thus better user acceptance).
Cons: costly and longer implementation period. Forcing designers to compromise their principles or concepts, harming the final product. Only applicable when there exists current solution. When no current solution, the only way is to invest sufficient time into ethnographic observation.

4.1 Prototyping

Prototypes: not functional, can be hand drawn. Intended to visualize design to users and make conceptual mismatch present itself earlier. ***Pros***: Money-saving, experimenting, keep design user-centered, and easy to throw away.

High-fidelity: looking like the product. **Low-fidelity**: details missing, *e.g.* storyboards (series of sketches showing users' traverse through a task).

4.2 Evaluating

Evaluation plans differ according to: stage of design, novelty of project, number of expected users, *e.t.c*. Depending on these factors, time and budget (5% to 20%) vary. However, continued assessing is required as perfect evaluation is impossible; despite problems found, decisions must be made, balancing between time, money and performance; unpredictable situations are extremely hard to test.

Expert Review: involving either expert designers or expert users. Conducted any time during development.
Methods include: **heuristic evaluation** (personal criticism from reviewer), **guidelines review** (only with Hi-Fi prototype, might need training on expert reviewer to master guidelines and interfaces), **consistency inspection** (only Hi-Fi, checking components like terminology in both interface and tutorials), **cognitive walkthrough** (asking expert reviewer to perform certain tasks and observe whether they behave as the designer expected) and **formal usability inspection** (designer justify ideas to expert reviewers who ask questions).
Problems: different experts may give conflicting advice.

Usability Testing and Labs: two areas separated by half-silvered mirror, one for participants, the other for observers. Participants should be representative of the user group, must be voluntary and informed of participation.
Variations: **videotaping** (recording participants' behavior) and **think aloud** (participants speak their thoughts), **paper mockups**, **competitve usability testing** (compare to similar products), **universal usability testing** (test with highly diverse environments including users, platforms, hardware *e.t.c*) and **beta tests**.

Questionaires and Survey: Keys include clear goals in advance, and focus items to attain the goals. Ask users for subjective impressions about task actions, designs, *e.t.c*. Goals might include: discover user background, personality style, *e.t.c*. Survey questions are ideally based on existing questions, reviewed by colleagues and pilot tested. Not as good as direct activities (which might lead to unexpected discoveries), and important to pre-test questions (understandability and bias).

Acceptance Test: (large projects) objective and measurable goals for performance set in advance, *e.g.* according to measures of usability.

Continuous Feedback (evaluation during active use): **(1)** interviews of individual users and group discussions, **(2)** user data logging (adapt software architecture to collect data), **(3)** provide online consultants, **(4)** e-mail suggestion box.

5 Humans

Among all the senses (including balance, body pose, *e.t.c*), sight and hearing is considered most.

Vision: 220° horizontally and 120° vertically. Only 5° of scene in high resolution and alternating bright/dark lines can be distinguished at 0.01°. Brightness sensitivity is at most 256 levels. These biological facts allows us not to waste time and money developing useless high-resolution screens.
Visual Perception: either **bottom-up** (combine low-level features into abstract mental model) or **top-down** (test prior model based on observation of low-level features).

Gestalt Grouping Principles: (bottom-up) tokens are grouped together by proximity (spatially near), similarity, same moving way, lying along smooth curve, forming a

closed boundary and symmetry. Therefore spatial layout is carefully designed to help user appreciate.

Phi Phenomenon: motion perceived from sequences of discrete images.

Judder: jerky motion perceived due to insufficient frame rate.

Context: (top-down) prior conditioning to overcome noise and ambiguity in low-level features, *e.g.* different "X"s have different meaning but we can distinguish each other.

Hearing: psychoacoustic qualities include pitch, loudness and timbre (quality). Sound localization through loudness for high-freq. voice, time elapses for low-freq. voice. Alternatively, pinna notch filters different frequencies, allowing people to identify directions using single ear. Acoustic signal → phonemes → syllables → words.

Equilibrioception: sense of balance.

Proprioception: sense of body position.

Attention Control: allocating mental resources. Two forms: **bottom-up** (stimuli-driven, changes and outliers), **top-down** (goal-driven, requiring conscious effort, *e.g.* cocktail party problem, diminishing bottom-up mechanisms when happening).

Pre-Attentive: before focusing attention, automatically perceives information, *e.g.* identifying red circle among blue ones. Good designs make important informatoin stand out pre-attentively.

Memory: *(short)* sensory → short-term → long-term *(long)*.

Two types of long-term memory: **declaritive** (facts and knowledge, **episodic** (memory of events) and **semantic** (structured concepts)) and **procedural** (skills, how to do sth.).

Long-term memory done through repetitive practice, affected by total exposure time, distribution of effect (done in intervals better), familiarity of context and mnemonics.

Reasoning: **deductive**, **abductive** (guess cause based on effect), **inductive** (general rules based on observations) and **analogical mapping** (cat→kitten, then dog→puppy).

Problem Solving: (problem space theory) goal state and initial state. Operators to go from one state to another. Solution is a sequence of operators. Solving through (1) learning operators, (2) exploration (including heuristics and planning).

Skill Acquisition: (ACT-R theory) simple rules (declarative memory, slow) → compile into procedural memory and composition of rules to make complex sequences → experts fine-tune rules.

Mental Model: A user's expectation of how something behaves. UI should fit users' mental model (no gulf of execution and evaluation). Different levels of mental models: **physical stance** (focusing on basic rules and properties, *e.g.* mouse moved 1cm is 50 pixels on screen), **design stance** (focusing on functions and usage, *e.g.* scroll the scroll bar to read more content) and **intentional stance** (focusing on intention, belief and motivation, *e.g.* avoid the attack of a video game monster).

Affects: 19 basic emotions, positive, neutral (only surprise) and negative. Composite emotions include smugness = happiness + contempt.

Fitt's Law of Movement Modelling: Models the speed of pointing to a target on table. $T = a + b\log_2\left(\frac{D}{W} + 1\right)$ where T is movement time, D is distance, W is target width, a and b are device dependent constant.

Intentional Communication: **linguistic** (use languages, including sign language), **iconic** (sketches, signs, tissue to reserve table) and **gestural** (physical action like nods). In contrast, non-intentional communication has body language or vocal language, related to people's affective state.

6 Human-Computer Interfaces

Pointing methods: **relative pointing** (mouse and touchpad, velocity of device → velocity on screen), **absolute pointing** (stylus are accurate but unintuitive, touch is on contrary, aimed-pointing is low in accuracy), **steering** (displacement of device → velocity).

Displays: physical size (by diagonal length), aspect ratios, pixel resolution, **viewing angle** (max off-center angle to maintain high display quality), **field of view** (visual angle the display takes up, related to immersion), **pixel density** (pixels-per-inch, 300 PPI around 25cm achieves human retina limit), **brightness** (peak luminance), **black level** (luminance of black pixels, must be low in dark places), **contrast** (peak luminance divided by black level).

7 Interaction and Design Concepts

Two types of interaction: communication (instruction or conversation) and manipulation (object or ego manip.).

Peripheral Feedback: Requiring little attention and users may ignore. *e.g.* modeless feedback (status bar), augmented reality.

(1) Interaction as Instruction: Users give instructions, *e.g.* command-line and menu selection. The action of typing or selecting doesn't physically relate to intended action. Response not instantaneous.

(2) Interaction as Conversation: Seems more like a dialog where computers give substantial feedback but not directly follow instructions. Instead computers confirm instructions, counter user proposes or promise without doing right away. *e.g.* iPhone Siri.

Five categories of utterances: **assert** (stating existing truth), **direct** (request sth.), **commit** (make promises), **express** (state attitude or emotion) and **declare** (define new truth).

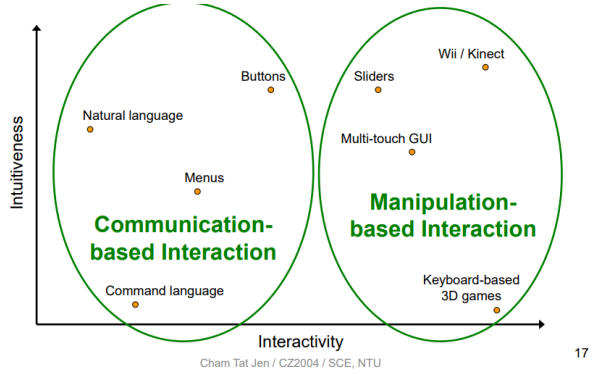
(3) Interaction as Object Manipulation: Users manipulate virtual objects or items. *e.g.* Multi-touch screens.

(4) Interaction as Ego Manipulation: Users move mental selves around. *e.g.* 3D games.

Interaction attributes: **interactivity** (how actively is user engaged) and **intuitiveness** (how quickly can users learn to use).

Interactivity: affected by the time to input an action and the time to respond. Coomunication-based → low interactivity; manipulation-based → high. Higher interactivity ⇔ engaging but computationally costly.

Intuitiveness: Ease of using an interface, related to user's familiarity with other softwares of the same type, *e.g.* motion-based controller Wiimote is more intuitive than traditional gamepad.



7.1 Software Behavior

Software postures: **sovereign** (monopolize user attention for long time), **transient** (occasionally catch attention for short duration), **daemonic** (silent/invisible, *e.g.* network and volumn icons).

Being ***empathetic***: Users' common negative affects include frustration (caused by excise) and fear (of doing wrong action). No complete avoidance (by perfect usability), but can mitigate through empathy. *e.g.* batch operation and empathetic error messages (express genuine concern, provide helpful options and convey gratitude to users).

Being ***considerate***: Consider a good host's behavior with a guest. Get **proactive** (know users well and predict their needs), **flexible** (easily reversible, no forcing users, adaptive to different user actions and gracefully fail), and **deferential** (avoid unnecessary dialogs).

Anthropomorphism: imiating humans using NLP, visual appearance. Gender and personality is considered.

7.2 Design Concepts

Affordance: Interaction attribute of permitting which actions. Good design → clearly perceived affordance. Affordance is only related to operations but not effects.

Metaphor: Mapping to real-world interactions. *e.g.* GUI desktop, trash bin.

Idioms: very widely-used routines. *e.g.* resizing windows by dragging on borders, cascading folders, WASD. Most are idiomatic instead of metaphoric.

Choice Limitation: Unconstrained operation for keyboard and pointer (unfriendly for novice users), so idioms or choice limitations are adopted. *e.g. (tight)* checkboxes → multiple choices → menus → sliders → text boxes → command line *(unlimited)*.

Context Awareness: Determine use's intention using context information. *e.g.* understanding abbreviations through geographical locations, 3D modeling with 2D GUI.

Design Patterns: Reusable past solutions including visuals, core ideas and techniques. Patterns include: *(almost-complete)* templates (*e.g.* PPT themes) → widgets (idiomatic GUI components, contained in GUI builders) → design guidelines (to ensure consistency) & pattern languages (to solve specific problem *e.g.* refreshing the page) *(abstract)*.

Pattern Language: collection of best solutions to design problems. Each pattern includes *context* (of encountering the problem), *problem* (description) and *solution* (solution steps and key considerations). ***Pros***: Non-experts use this to generate good design. Those solutions are already well-tested, and key steps and considerations are conveyed.