



Center for
**LifeLong
Learning
& Design**

University of Colorado at Boulder

Wisdom is not the product
but the lifelong attempt

AI and Design

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Reading — D. Bobrow: “Dimensions of Interaction”, AAAI-90 Presidential
Address,
AI Magazine Fall 91, pp 64-80

AI Course, Fall 1997

The Sciences of the Artificial

Understanding the Natural and the Artificial World

- **natural science: “how things are”**
 - knowledge about natural objects and phenomena
 - primary interest: analysis
 - examples: physics, chemistry
- **sciences of the artificial: “how things might be (and ought to be in order to attain goals and to function)”**
 - knowledge about artificial objects and phenomena
 - primary interest: synthesis
 - artificial things are as they are only because of a system's being molded, by goals and purposes, to the environment in which it lives
 - examples: engineering, medicine, business, architecture, painting

Design

- **Definition:**

Everyone designs who devise courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a state (Simon, “Sciences of the Artificial”, p 130)
- **examples:** architects, doctors, managers, politicians, teachers, artist,
- **Alan Kay (Scientific America, Sept 84, p 57)**

“molecular biology has the advantage of studying a system already put together and working; for the composer of software the computer is like a bottle of atoms waiting to be shaped by an architecture he must invent and then impress from the outside”
- **generic design — does it exist?**
 - design as an activity has a distinct conceptual and cognitive realization from non-design activities
 - it can be abstracted away from the particulars of the knowledge of a specific task or discipline and studied in its own right

Design Deals with Wicked or Ill-Defined Problems

- there is no definitive formulation of a *wicked/ill-defined* problem. For any given *tame/well-defined* problem, an exhaustive formulation can be stated containing all the information the problem-solver needs for understanding and solving the problem
- wicked problems have no stopping rule. In tame problems, problem solvers know when they have done the job. Problem solvers terminate work on a wicked problem, not for reasons inherent in the 'logic' of the problem
- solutions to wicked problems are not “true-or-false”, but “good-or-bad”
- the existence of a discrepancy representing a wicked problem can be explained in numerous ways — the choice of explanation determines the nature of the problem's resolution.
- in design: the aim is not to find the truth, but to improve some characteristics of the world where people live

How Should We Study (Complex) Designs?

from R. Dawkins: "The Blind Watchmaker"

- biology is the study of complicated things that give the appearance of having been designed for a purpose
- physics is the study of simple things that do not tempt us to invoke design
- treat complex human-made artifacts (e.g., computers, airliners, cars, books) as biological objects
- the behavior of physical, non-biological objects is so simple that it is feasible to use existing mathematical language to describe it
- a complex thing is something whose constituent parts are arranged in a way that it is unlikely to have arisen by chance alone

Artificial Intelligence and Human Intelligence

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A Design Perspective

- the organization of components, and not their physical properties, largely determines behavior
- computers are organized somewhat in the image of humans
- computer becomes an obvious device for exploring the consequences of alternative organizational assumptions for human behavior
- psychology can move forward without awaiting the solutions by neurology of the problems of component design — however interesting and significant these components turn out to be

Design Perspectives Relevant to AI

- **satisficing versus optimizing**
 - optimal decision for an imaginary simplified world (operations research methods)
 - decisions that are “good enough” ---> "satisficing" solutions (heuristic search)
- **heuristic search** makes much weaker demands on the problem structure than mathematical tools of **operations research**
 - can cope with non-quantifiable variables
 - is applicable to non-numerical as well as numerical information

“The best is often the enemy of the good”

Evolution and Design

- **Design different from Evolution:**
 - guided
 - there is a goal (question: can we design without a final goal in mind?)
 - one can look back over a design and “clean it up”
 - one can examine failures and see what went wrong
 - faster than evolution (guidance, remembering previous successes and failures)
- **Is Design the same as Evolution?**
 - "installed base" problem (“qwerty” typewriter, English measurement system, Fortran/Cobol,
 - standards
 - knowledge is cumulative

The Shape of the Design: Hierarchy

The Problem of Modularity

- **claim:**
 - to design a complex structure, one powerful technique is to discover viable ways of decomposing it into semi-independent components corresponding to its many functional parts
 - the design of each component can then be carried out with some degree of independence of the design of others, since each will affect the others largely through its function and independently of the details of the mechanisms that accomplish the function
- **examples:**
 - functional programming
 - object-oriented programming
 - rule-based systems
 - nearly decomposable systems

Stakeholders and Ownership of Problems in Design

— Example: Designing the Denver Public Library

- 1991: final design competition
- 1995: construction finished
- requirement: 15 years without major modifications
- question: a library in the year 2010? — books, CD ROM, ---> we are not only designing for a given context: we construct the context
- client: city of Denver ---> committee (old librarian, techi, ...)
- who owns the problem??
 - client(s), designers, customers, specialist,
 - architect, structural engineer, contractor, bricklayer,

Three Generations of Design Methods from the History of Architectural Design

- **1st Generation (before 1970):**
 - directionality and causality
 - separation of analysis from synthesis
 - major drawback: perceived by the designers as being unnatural; does not correspond to actual design practice
- **2nd Generation in the early 70'es:**
 - participation — expertise in design is distributed among all participants
 - argumentation — various positions on each issue
 - major drawback: insisting on total participation, neglecting expertise possessed by a well-informed and skilled designer
- **3rd Generation (in the late 70'es):**
 - inspired by Popper: the role of the designer is to make expert design conjectures
 - these conjectures must be open to refutation and rejection by the people for whom they are made (---> end-user modifiability)

Dimensions of Interaction

Beyond the “Isolation Assumption” of AI

(Bobrow, AAAI Presidential Address, 1990)

isolation assumption as the dominant goal of AI:

- single agent
- fixed knowledge
- specified goal
- agent was disconnected from the world (no sensors, no effectors, no connection to other intelligent agents)
- agents which were intelligent, but deaf, blind, paraplegic and individuals

Dimensions Of Interaction

communication

- common ground
- using intermediaries

coordination

- share resource and work towards some common goal
- formalization does not need to be complete to be useful in aiding human coordination

integration

- understand the place of AI in the broader fields of human endeavor
- integration with work practices
- integrating action and information worlds makes learning more effective

Communication

common ground:

- omniscience: system designers believe that they can foresee all possible uses and the background of all future interactions with the system
- omnipotence: ability to change the system to meet any contingencies
- extending common ground
- grounding in experience
- negotiating common ground

using intermediaries:

- cognitive coprocessor (e.g., exploit visual processing)
- distributed knowledge bases
- real-time mediator (e.g., to transform a flood of data into a stream of more useful information)

Coordination

resource management:

- central planning model
- market model (decentralized control; e.g. Starlogo with thousands of turtles)
- the world as a resource

goal coordination

conversation-based coordination

- example: semi-formal systems

Integration with Work Practices

- **NP-hard Trap:** worrying about the worst-case analysis can sometimes lead to pretty mathematics, but poor design and engineering
- **AI-hard Trap:** we need not live by AI alone
- **Business Integration:** integrate programs with advisers, guides, coaches, critics (see the appearance of such components in Word, Excel, Pagespinner,)
- **Information Integration:** action/experience + reflection, making argumentation serve design (example: Janus = Janus-Construction + Janus-Argumentation)

Challenges

- systems that are open and can grow (from knowledge acquisition to knowledge construction) ---> **evolution**
- to be intelligent is to be intelligent about something ---> **domain-orientation**
- provide the involved people with a sense of ownership, participation, influence
---> **human-centered design**

Information Access and Presentation: Making People Smarter

general observation:

Because better information means better decisions, decision makers naturally want access to large quantities of information expressed in diverse forms. But the world wide web, new sensor technology, and other information sources have combined to create quantity and diversity, such that it has become increasingly difficult to provide decision makers with the right information, at the right time, in the right quantity, in the right form.

Examples:

- the Enhanced Reality Project: X-Ray Vision for Surgeons
- the Human-Computer Interaction Project (creating the Infrastructure: Wall-sized displays, essentially unlimited amounts of computation is almost free)
- information access via natural language and the www — without access technology, much on line information might as well be in a black hole
- simulation systems that enable medical students and doctors to *feel* what it is like to suture vessels and learn new procedures.
- the Intelligent Room: a basis for intelligent collaborative problem solving

Beyond Expert Systems: Making Computers Smart Enough

Past:

The rise of rule-based expert systems in the 1980s was predicated on the idea that computers could do what human experts could do, only less expensively. Those interested in trying out the then-new expert-system technology were told that the first problem tackled should be doable by a person in more than an hour and less than a week.

Today: the emphasis is not on doing what people do. Instead, the emphasis is on exploiting opportunities to do tasks that people cannot do alone ---> such as:

- digging regularity out of data in the search for new pharmaceuticals,
- capturing design rationale and exploiting captured rationale to improve product design, and
- working through tediously complex calculations to better guess what a computer user needs to know.

Examples:

- **Building robots:** From theories of intelligence to cleaning up land mines and exploring the surface of Mars.
- **Database Mining:** User interface issues---how to express goals and constraints, and how to display high-dimensional results---are important areas where progress is needed (and expected)

Examples -Continued

Rationale capture:

- preserving the thought as well as the conclusion — to capture much of the process involved in design and decision making, as well capturing the final outcome
- the additional information---about rationale, alternatives considered and rejected, and the expertise underlying the result--- is an enormously valuable commodity, perhaps the most valuable asset of a corporation in the information age.

Knowledge Management: Maximizing Intellectual Capital

- Best practices transfer well only when properly supported by help, training and experienced people.
- Technologies of collaboration are emerging -- telepresence, interactive learning environments, and virtual collaboratories.
- Reward examples of information sharing, else information hoarding is rational.
- To design workable knowledge management system's, make sure HCI design is sensitive to work practice behavior.

The role of entertainment as an information-technology driver

- AI can be used to make entertainment much more interactive and tailored to the interests of individuals
- Alan Kay: from experience ---> reflection

Set of Research Projects Addressing these Issues — L3D

- common ground ---> Intersim, Eva
- using intermediaries ----> human-centered intelligent support systems, McGuckin
- formalization does not need to be complete to be useful in aiding human coordination ----> critiquing, incremental formalization,
- sharing ---> organizational learning, organizational memories, Gimme, Behavior Exchange
- integration with work practices ---> domain-oriented design environments
- open, evolvable systems: SER model, end-user modifiability, Visual Agentalk, Dynasite
- integration of the physical and the computational world: Hypergami, Logo, Fischer-Technik, Lego, Lego-Logo, Legosheets, Crickets

Trade-offs Between Different Design Media

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Real World

- + no abstraction processes are required
- + tests are reliable (they are carried out with the real thing)
- tests are difficult to carry out (controlled experimental situations are hard to generate)
- only one level of description; simplification or abstraction is very difficult
- costs may be very high (especially if existing structures have to be modified)
- phenomena have to be explained or predicted with all their particularities

Trade-offs Between Different Design Media



Technical Construction Systems (e.g.:Lego, Fischertechnik)

- + many natural laws are valid (e.g., an artifact constructed the wrong way will fall over); it is possible to explore the world by providing a means to act on it concretely
- + the dynamics of models can be studied
- + costs are relatively low compared to the construction of prototypes in the real world
- + undoing things is easy
- in general there is only one additional level of description (compiling is restricted)
- resource limitations are crucial (number of available parts; diversity of parts)
- models can not be parameterized

Trade-offs Between Different Design Media

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Paper and Pencil

- + arbitrary many levels of descriptions
- + no resource limitations with respect to material; but we hit the boundaries of human rationality and imagination very quickly
- + cheap to modify; easily available
- + diagrams help to visualize structures and experiments
- hard to modify with respect to time (see advantage of text processing system)
- static, no dynamic behavior; we cannot dynamically recode the appearance of a structure
- the laws of nature are not valid (e.g. things do not fall over; experiments with nature are impossible)

Trade-offs Between Different Design Media: Computer

- + ease of modification
- + compiling allows us to change a glass-box into a black-box (i.e., we can generate several levels of description)
- + the dynamics of a model can be simulated
- + almost no limitations which systems can (at least potentially) be modeled
- + UNDO can be provided for ease of experimentation
- + models can easily be parameterized and irrelevant details can be hidden
- + the natural laws can be modeled; we can even model worlds which do not obey the laws of physics
- the natural laws are not operational
- the modeling requires an additional level of abstraction
- non-trivial use requires (at least today) special knowledge