ECOLOGICAL INTERFACE DESIGN (EID)

An Ecological approach to Interface design
KEYS FOR USER CENTERED DESIGN

- User studies: identify what users want
- Rapid paper prototyping: get user feedback
- Usability testing: with users to identify usability problems
PROBLEMS WITH UCD

- Few organization managing to implement the UCD process
  - User issues
  - Organizational commitment
  - Developer skills
  - Resource constraints
USER’S LIMITATION

- Experience
- Knowledge
- Expectation
- User contribution
- User agreement
- User diversity
OTHER PROBLEMS

- User studies too easily confuse what users want with what they truly need.
- Rapid iterative prototyping is too often a sloppy substitute for thoughtful and systematic design.
- Usability testing is a relatively inefficient means of finding problems that often could have been avoided through proper design.
CHANGING REQUIREMENTS

- Tasks
  - Knowledge intensive
  - Cooperative
  - Creative
  - Variable context
  - Leisure, entertainment
CHANGING REQUIREMENTS

- **Users**
  - Wide range
  - Very different skilled and capabilities
  - Anonymous users
  - Different lifestyles/attitudes
GÖTEBORG TRAFFIC!
A lot more ADAS

- Distance Warning
- Radar Braking
- V2V
- Digital Maps
- Night Vision
- Curve Management
- Railroad Crossing Collision Avoidance
- ISA
- Driver Vigilance Monitoring
- Satellite Positioning
- HAC
- Curve Warning
- EBD
- Honda Accord ADAS
- ABS
- Rear End Collision Avoidance
- By-wire Controls
- CAAS
- CWAB
- FCW
- FCM
- City Safety
- Smart Headlamps
- ACC
- Stop & Go
- LCA
- Enhanced Night Vision
- Perception of Vehicle Surroundings
- BLIS
- LDW
- Smart Restraint Systems
- TCS
- Driver Health Monitoring
- VSC
- Roll Stability Control
- Tire Pressure Warning
- DAC
- Smart Highways
- Parking Assistance
- Backup Monitor
- Assistance
WHAT KINDS OF ADAS ARE ALREADY IN THE MARKET?

- distance alert
- adaptive cruise control
- blind spot information
- lane departure warning
- night vision
- driver monitoring
DESIGN BY USER?

Control over 300 functions while drive....
FOR COMPLICATED SYSTEMS

- Technical oriented design?
- User-centered design?
- Other approach?
HERB SIMON’S ANT ON THE BEACH

Goal-driven
AFFORDANCE

- An **affordance** is a quality of an object, or an environment, that allows an individual to perform an action

--- Wikipedia
**ECOLOGICAL APPROACH (GIBSON)**

**Affordances** are *perceivable possibilities for action*. We perceive in order to operate on the environment, as perception is designed for action:

- surfaces for walking, handles for pulling, space for navigation, tools for manipulating, etc.
GIVING MEANING TO WORLD

- People endow their experiences with meaning
  - Will see world around them in terms of relevant cues and expectancies in service of larger goals
GIVING MEANING TO WORLD

- Notion of filters unnecessary if humans pursue goals and give world meaning accordingly
  - Selective attention not subtractive or negative
    - Constructive capability to function in cognitively noisy environments
GOAL-DIRECTED BEHAVIOR

- Not just stimulus or feedback-driven
  - Anticipation of changes in world
    - Mental model of system and situation
- People *manage* entire *situations*
  - Assess situation in terms of possible solutions
  - Find or keep at least one solution to reach goal
Role of World

- Continuous cycle of transactions *with* world
- Not single reactions *to* single cues in world
- No separation between cognition and action
ECOLOGICAL APPROACH

It is important to begin by analysing the environment before analysing what people are doing, or how they are doing it, or what they know.

It is not possible to understand human behaviour without simultaneously understanding the environment in which people are acting.
ECOLOGICAL INTERFACE DESIGN

Some important contributors

- Gibson (from 1953? -)
- Jan. Rasmussen (from 1985 -)
- Kim Vicente (1990 -)
- John Flach (1998 -)
- Catherine M. Burns (2000 -)
ECOLOGY CAN BE ANY OBJECT, EVENT OR SITUATION
MEANING IN THE WORLD

- Meaningfulness independent of observer
  - Meaning not constructed, or added through processing, but the raw material
  - Perception-Action coupling happens in world, not in brain
Classes of Constraints

- Constraints on action
- Functional constraints
- Constraints on information
Meaning arises within the ecology and reflects the constraints on action in that ecology.
EXPERTISE REFLECTS *DISCOVERY OF SIGNIFICANT CONSTRAINTS WITHIN THE ECOLOGY*
ECOLOGICAL APPROACH

• "Experts perceive large meaningful patterns in their domain" (Cooke, 1992, p. 33)
Pattern may be significant because of its implications for some function

- Meaningful because it specifies what can or should be done next
ECOLOGICAL APPROACH

- Problem analysis steps:
  - First analysing environment before analysing what people are doing, or how they are doing it, or what they know.
**CLASSICAL VS. ECOLOGICAL**

- **Classical:**
  - Human cognitive system imposes constraints on the processing of information from the world

- **Ecological:**
  - Environment imposes constraints on goal-directed behavior
TRADITIONAL VS. ECOLOGICAL

**Traditional**
- Emphasis on analysing human characteristics
- Link between perception and action is the brain
- Meaning is ‘added’ (interpreted)

**Ecological**
- Emphasis on analysing the environment
- Link between perception and action is the environment
- Meaning is relative to the functional goals of a work domain (significant)
THREE TYPES OF EVENTS

- The user will have to deal with three different types of events in complex domains:
  - familiar events
  - unfamiliar but anticipated events
  - unfamiliar and unanticipated events
EVENTS IN A COMPLEX DOMAIN

The EID has been developed in order to deal with all three kinds of events and to offer the operator the most appropriate support in any situation.
Complex work Domain

Question: How to describe domain complexity? Required: A domain representation formalism

Interface:
- content
- structure
- form

Human operator

Question: How to communicate the information? Required: A model of the mechanisms that people have for dealing with the complexity
"Catch and Toss" Models

- Goal formation
- Intention
- Evaluation
- Interpretation
- Planning
- Action
- Perception

The world
THREE LEVELS OF COGNITIVE CONTROL

Three levels of cognitive control:
  - Skill-based control
  - Rule-based control
  - Knowledge-based control

Each level has its own design principle
**SKILL-BASED BEHAVIOUR (SBB)**

Automated behavioural patterns are used at this level.

“To support interaction via time-space signals, the operator should be able to act directly on the display, and the structure of the displayed information should be isomorphic to the part-whole structure of movements”
RULE-BASED BEHAVIOUR (RBB)

Cognitive control on this level depends on a set of cue-action mappings.

“Provide a consistent one-to-one mapping between the work domain constraints and the cues or signs provided by the interface”
**Knowledge-Based Behaviour (KBB)**

At this level of cognition, problem solving operations on a symbolic representation come into play.

“Represent the work domain in the form of an abstraction hierarchy to serve as an externalised mental model that will support knowledge-based problem solving”
## Skills, Rules, Knowledge

<table>
<thead>
<tr>
<th>Performance Level</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill based performance</td>
<td>Automatic, unconscious, parallel with other activities</td>
</tr>
<tr>
<td>Rule based performance</td>
<td>Recognizing situations and following applicable procedures</td>
</tr>
<tr>
<td>Knowledge based performance</td>
<td>Conscious problem solving</td>
</tr>
</tbody>
</table>
NOT ALWAYS ALL STAGES

The world

KB
RB
SB
GOAL OF EID

○ support for all three levels
○ Keep in lower level if necessary
Lower levels Are easier
Lower levels Are preferred
Complex tasks Require all levels
Greater the demand, Higher the level
Greater the skill, lower the level

Design for use of lower levels
All levels need to be supported

Goal for interface design:
Design interfaces that do not force cognitive control to a higher level
That the demands of the task require, but that also provide the
Appropriate support for all three levels
ECOLOGICAL INTERFACE DESIGN (EID) (DEFINITION)

Ecological Interface Design (EID) is a framework that is based on the skills, rules, knowledge taxonomy of cognitive control. It has been developed for complex human-machine systems with direct manipulation interfaces.
The goal of an ecological work analysis is to uncover the meaning in situations. To discover the significant constraints in a particular domain.
IDENTIFYING CONSTRAINTS BY USING MULTIPLE PERSPECTIVES

- Published accounts of standard practices
- The opinions of various experts
- Field observation within the particular domain
- Lab experiments
- Experiments with synthetic task environments
OPINION OF VARIOUS EXPERTS

- ‘Who is the expert?’
- Different opinions according to field of experience
- Ecologically more representative:
  - multiple experts
  - multiple interviewing tools
FIELD OBSERVATIONS WITHIN THE DOMAIN

- Overcome experts limitations in awareness
- Overcome experts misconception of own behaviour
- Active observation:
  - reveal difficult-to-recognise constraints
LAB EXPERIMENTS

- Manageable chunks of situation
- Observe event repeatedly
- Important to preserve the meaningful aspects of the situation
- Understand how the constraints within a situation shape performance
SYNTHETIC TASK ENVIRONMENTS

- Constraints can be controlled and manipulated
- Identify performance invariants
- Simultaneous measurement at multiple levels
- PROBLEM!
ECOLOGICAL INTERFACE DESIGN

- A good representation will simultaneously represent:
  - Relevant function
  - The goal states
  - Current states
  - Functional consequences of time
  - Critical boundaries for action
THREE DESIGN PRINCIPLES

- Skill based behaviour – workers should be able to act directly on the interface
- Rule-based behaviour – there should be a consistent one-to-one mapping between the work domain constraints and the perceptual information in the interface
- Knowledge-based behaviour – the interface should represent the work domain in the form of an abstraction hierarchy to serve as an externalized mental model for problem solving
COGNITIVE WORK ANALYSIS:
AN ECOLOGICAL APPROACH TO THE DESIGN OF COMPUTER-BASED WORK
WANTED

- Systematic framework for designing computer-based work in complex sociotechnical systems
PERSPECTIVE

- Ecological approach

Ecological Approach

Physical Reality, Social Reality

Environment Worker

Workers' Mental Models, Strategies, and Preferences

Cognitivist Approach
Cognitive Work Analysis

- Objective
  - design to support worker adaptation

- Structure
  - 5 layers of behavior-shaping constraints
  - modeling tool for each layer
Cognitive Work Analysis

Human Behavior over time

Behavior-Shaping Constraint
Work Domain
Control Tasks
Strategies
Social Organization and Cooperation
Worker Competencies
Cognitive Work Analysis

- Work Domain
- Control Tasks
- Strategies
- Social-Organizational
- Worker Competencies

Ecological

Cognitive
Cognitive Work Analysis
Cognitive Work Analysis

Constraint Boundaries

Space of Action Possibilities

Trajectory 1

Trajectory 2
MODELLING TOOLS

- Work domain
- Control tasks
- Strategies
- Social-Organization
- Competencies

=> Abstraction hierarchy
=> Decision ladder
=> Info flow maps
=> All of above
=> SRK taxonomy
## Abstraction Hierarchy

<table>
<thead>
<tr>
<th>Decomposition</th>
<th>Total System</th>
<th>Subsystem</th>
<th>Function Unit</th>
<th>Sub-Assembly</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstraction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional Purpose</td>
<td>No communication to tape or disk</td>
<td>Test program</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abstract Function</td>
<td>Joint node in information paths</td>
<td>Program and flag conditions</td>
<td>Flags and conditions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generalized Function</td>
<td></td>
<td>Instructions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Function</td>
<td>Interface to DEC - writer</td>
<td>Not keyboard but -</td>
<td>Manipulation of power supply. Study function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Form</td>
<td></td>
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</tbody>
</table>

1. Joint node in information paths
2. Program and flag conditions
3. Instructions
4. Instructions
5. Test program
6. Multiplexer
7. Interface to DEC - writer
8. Not keyboard but -
9. Manipulation of power supply. Study function
10. Flags and conditions
11. Not keyboard but -
12. Interface to DEC - writer
13. Study function
14. Transistor short-circuit
15. Study function
DECISION LADDER

1. ALERT
2. ACTIVATION
3. OBSERVE
4. SET OF OBSERV.
5. IDENTIFY
6. DEFINE TASK
7. TASK
8. FORMULATE PROCEDURE
9. PROCEDURE
10. EXECUTE
11. GOAL STATE
12. SYSTEM STATE
13. INTERPRET
14. EVALUATE
15. AMBL.-Guity
16. ULTIM. GOAL

- States of knowledge resulting from data processing
- Data processing activities

what's the effect?
which goal to choose?
which is then the goal state?
what lies behind?
what's going on?
which is the appropriate change in operating cond.?
how to do it?
**Decision Ladder**

- **Evaluate**
  - Which goal to choose?
  - Ambient goal
  - Ultimate goal

- **Interpret**
  - Which is then the goal state?

- **System state**
  - What's the effect?
  - Yes!

- **Identify**
  - What lies behind?

- **Set of observations**
  - What's going on?

- **Observe**
  - System ready?

- **Alert**
  - Activation

- **Task**
  - How to do it?

- **Define task**
  - Which is the appropriate change in operating cond.?

- **Goal state**
  - Then... (Schedule, order)

- **Process procedure**
  - Execute
STRATEGIES

Pattern Matching

MATCH?

Failed System

Label of Reference in Terms of Cause, State, Event, Task, Etc.

Scan and Select

Tactical Rules for Selection of Next Entry to Test

Library of Failed State Symptoms

Yes

Found

No
### Social-Organizational

<table>
<thead>
<tr>
<th>Purposes</th>
<th>Whole Body</th>
<th>System</th>
<th>Organ</th>
<th>Tissue</th>
<th>Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balances</td>
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<td>Processes</td>
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<td>Physiology</td>
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<tr>
<td>Anatomy</td>
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</tr>
</tbody>
</table>

- **Anesthesiologist**
- **Surgeon**
SRK Taxonomy

Knowledge-Based Behavior
- Identification
- Decision
- Planning
- Symbols
- Goals

Rule-Based Behavior
- Recognition
- Association State/Task
- Stored Rules for Activities
- Signs

Skill-Based Behavior
- Feature Formation
- Automated Sensori-motor Movements
- (Signs)
- Signals
- Actions

Sensory Input
APPLICATION DOMAINS

- Aviation
- Command & control
- Computer software
- Electronic troubleshooting
- Engineering design
- Fossil-fuel plants ✓
- Hypertext retrieval ✓
- Library information retrieval
- Manufacturing
- Medicine ✓
- Nuclear power ✓
- Petrochemical plants
- Thermal-hydraulic process control ✓
**ABSTRACTION HIERARCHY (AH)**

- The Abstraction Hierarchy (AH) is a 5-level functional decomposition used for modelling the work environment, or more commonly referred to as the work domain, for complex sociotechnical systems (Rasmussen, 1985).

- In the EID framework, the AH is used to determine what kinds of information should be displayed on the system interface and how the information should be arranged.
ABstraction hierarchy framework

- Functional purpose
  - the goals and purposes of the system
- Abstract function
  - describes the underlying laws and principles that govern the goals of the system
ABSTRACTION HIERARCHY FRAMEWORK

- Generalized function
  - explains the processes involved in the laws and principles found at the AF level
- Physical function
  - reveals the physical components or equipment associated with the processes identified at the GF level
- Physical form
  - describes the condition, location, and physical appearance of the components shown at the PFn level
EID and IP

Information processing approach to the task analysis

Human

Attention
Memory
(knowledge)

Sensors

perception

Integration

Action

Goals
Meanings

Ecological approach to the work analysis

Environment

Organization

Technical systems

Work
Many tasks

Interface
INTERFACE DESIGN

- An interface that contained physical and functional (P+F) information at all levels of the abstraction hierarchy was created.
SUMMARY

- People has goal-orientated behaviour and constantly searching for meaning
- The concept of ecology
- Skill, rule, and knowledge
- Ecological work analysis
- Work domain analysis
- Abstraction Hierarchy framework
- Principle for ecological interface design