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CLASSIFICATION	SYSTEM NUMBER 511909
UNCLASSIFIED	

TITLE

Designing for Performance in Human-Machine Systems

System Number:

Patron Number:

Requester:

Notes: Paper #35 contained in Parent sysnum #511874

DSIS Use only:

Deliver to: CL

#511909 (35)

Designing for Performance in Human-Machine Systems

by Norman G. Vinson, Janice A. Singer and Marceli Wein

Institute for Information Technology
National Research Council, Canada
Ottawa, ON K1A 0R6

ABSTRACT

This paper discusses how user-centered design improves the performance of human-machine systems. The overall performance of such systems is a function of the individual performance of its two major components, the human user and the machine, and the performance of the interface between these two components. Accordingly, errors and inefficiencies can result from the technological limitations of the machine, from the user's human limitations, and from limitations of the interface.

In the vast majority of cases, system development effort is focused on advancing the technology, with little, if any, regard to the human-machine interface or the needs of the human users. Ignoring a major component of the human-machine system, the human, means that potential gains in efficiency and accuracy will not be realized. Worst yet, additional sources of errors and inefficiencies can be introduced by modifying the interface without regard to the user.

In contrast, user-centered design takes into account the needs, characteristics, tasks, and limitations of the users. Based on an understanding of the user and his tasks, the designer can specify the functions the machine must perform so that the tasks are accomplished successfully by the human-machine system. This reduces some of the errors and inefficiencies that can be attributed to the machine component. Knowledge of human limitations can guide interface design to avoid pushing the user beyond his capabilities, thus mitigating the effects of human limitations. Finally, more efficient interfaces are designed through knowledge of how users perform their tasks.

The goals of user-centered design, its cost-justification, and some of its more practical techniques are presented in this paper. Moreover, these design techniques are illustrated by referring to the design of the UNIT (Universal Nondestructive Inspection Tool) system.

Performance of Human-Machine Systems

- **System performance**
  - Errors
  - Speed
- **Sys. performance = f(human, machine, interface)**
- **User-centered design**
  - increase system performance
  - increase user acceptance of the system

Increased Performance: Examples of Results

- **Oscilloscope user interface redesign**
  - -> 77% increase in performance speed
- **User-centered design of flight deck for Boeings 575 and 767**
  - -> Aircraft can be operated with 2 rather than 3 pilots
- **User-centered design of interface for software destined for internal use**
  - -> Increased productivity calculated to produce 6.8 million $ US savings in 1st year.

User–Centered Design Saves Time and Money

- **Reduce total development time & cost**
  - Total development = development + post-delivery changes
- **In only 2 % of software projects, software does** not **require changes after delivery (Davis, 1990)**
- **About 50 % of code for user interface**
- **User centred design IDs real needs before development**
  - Change requirements; not system
  - Don't develop unneeded features & functions

    --> save time & money

User–Centred Design

- **User-centered design is**
  - an approach to design
  - a collection of techniques
- **Design fields practicing user-centered design**
  - Ergonomics
  - Human Factors
  - User-interface (UI) design, cognitive ergonomics, human-computer interaction (HCI)

Increasing Performance

tasks accomplished by human-machine system ->

- Sys. performance = f(human, machine, interface)
- **To increase performance**
  - make the interface mesh with user practices
    - user expertise transfers to new system
    - reduces possibility of failure
  - make the interface mesh with user cognition
    - user does not waste cognitive resources transforming data provided by the interface
    - interface can support user analysis and decision-making

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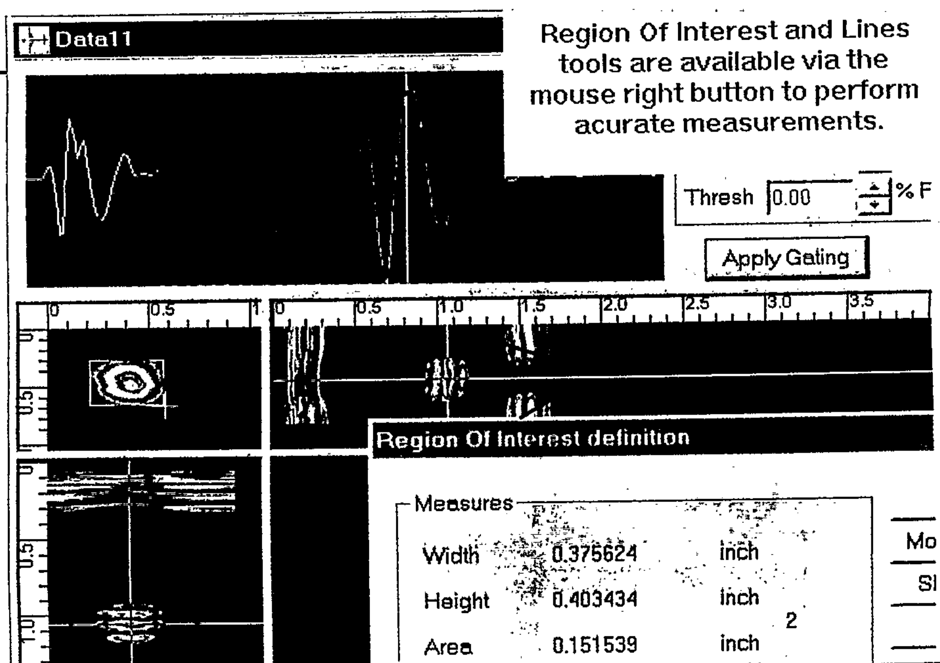
Example



NRC·CNRC

Increasing User Acceptance of the System

User participation in design

- **user contributes to system design**
- **shows respect for user's expertise**
- **makes user familiar w/ new system before implementation**
  - (removes "interface shock")

Match between interface & user

- **allows user to apply expertise**
  - user remains valuable
- **increases user familiarity w/ new system**
- **system is usable and useful; not frustrating**

How to Do User-Centred Design

1 Gather user-related requirements
- interviews
- observation
- analysis

2 Design based on 1

3 Test design using
- **mock-ups**
- **heuristics**
- **scenarios**
- **simulations**

iterate

4 Change design based on 3

5 Implement final design in application

Design quality = *f*(requirements gathering, testing)

User-Related Requirements

- **task analysis**
  - required data & heuristics or algorithms
- **organisational profile**
  - e.g. who decides what
- **user requirements & user profile**
  - e.g. user experience
  - e.g. types of users
  - e.g. frequency of use
- **environmental requirements**
  - e.g. lighting (too dark for typing ?)
  - e.g. mobility

Iterative Design and Testing

- **design based on user-related requirements**
- **test**
  - create low fidelity mock-up
    - e.g. paper & pencil
  - real user simulates task performance w/ mock-up
    - testers play role of computer (like puppeteers)
      - difficult for 3D
      - difficult for animation
- **change design, re-test, progressively increase mock-up fidelity**
  - cost of design change = f(mock-up fidelity)

Pros & Cons of User–Centred Design

Pros

- **system performance**
  - perf. = f(interface)
- **high quality interface design**
  - user reqts => quality
  - testing => quality
- **high (quality/dev. cost) ratio**
  - design changes made early => lowers dev. cost
- **lower prob. of failure**
- **user acceptance & satisfaction**

Cons

- **takes time up front**
- **change in user requirements**
  - circumstances change
  - users become more communicative
- **higher user expectations**
  - user wants bells & whistles
  - developer wants to minimise cost

Summary

- **User-centered design**
  - is an approach to design
  - is a collection of techniques
  - can be applied to a variety of projects
  - increases performance of human-machine systems