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TITLE

HFEICADD: Intelligent CADD for Human Factors in Design

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HFEICADD: Intelligent CADD for Human Factors in Design

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Abstract:

The HFEICADD system is a computer aided design tool to support the collaborative review of human factors issues in the design of naval vessels in Canada. This research and design project has resulted in the integration of a series of custom designed and off the shelf software products that facilitate the sharing of design criteria and review decisions over the life cycle of a vessel. This software suite, now in the final phases of development, has the potential to be used in any collaborative design environment to ensure that task data, design review data, and design decisions are captured and utilized by all project personnel.

1. Introduction

The design of a naval vessel includes the workstations and accommodations for hundreds of crew members. Human Factors Engineering (HFE) is, therefore, an important consideration in the ship design process. In Canada, the responsibility for HFE throughout the ship's life cycle is split between The Department of National Defence (and its divisions) and The Prime Design Contractor (and its sub-contractors).

As a result of this division of responsibility, HFE design criteria and decisions must be communicated and maintained across a diverse range of technical personnel and over an extensive period of time (typically greater than 10 years for the design process).

The inclusion of HFE considerations provides many challenges within the design process [1]. Those challenges exacerbate the problems posed by a design decision history spread over many years, the associated personnel turnover, and the geographic distribution of personnel responsible for design and development

In 1992, a requirements study was contracted by the Defence and Civil Institute of Environmental Medicine (DCIEM) to find ways and means to improve the design, evaluation and modification of shipboard workspaces for the Canadian Navy with respect to HFE criteria. The objective of the project, which was contracted to Humansystems Incorporated, was to investigate opportunities for CADD software to improve the application of HFE methods and data to the design of naval vessels. This involved understanding, at a gross level, how the overall design and development process occurred, what assistance was needed at what points in the process, and determining how computer aids might be used to provide the required assistance.

The result of the study was a concept for a Human Factors Engineering Intelligent Computer Aided Design Drafting (HFEICADD) system [2]. The system is now being built by Humansystems, Protogon, and Genicom, under a contract initiated by DCIEM let in 1994 [3]. The objective of the development is:

> "to improve the capability of the Human Engineering Section of the Directorate of Ship Engineering to address human factors engineering issues in ship design, particularly design review functions, by the development of a CAD based, modular, intelligent software tool."

To understand the role of this tool, it is best to provide some background on the ship design process, and the collaborative nature of the review of human factors issues in the layout of ship spaces.

Prior to construction, ship design progresses through a series of stages including Concept design, Feasibility design, Preliminary design, Contract design, and Detailed design. These stages are repeated on a smaller scale throughout the life cycle of a ship for modifications and upgrades. Human factors considerations throughout the design cycle include manning, habitability, and layout of workstations (displays and controls) in operations and communications spaces.

At the core of HFE activities is the need to optimize the relationship between user capabilities and the demands of tasks which are performed within the layout of the compartments under review [4]. In order to conduct such

a review, the designer and the reviewer must have some knowledge of the tasks to be performed, as well as the characteristics of the user population.

The importance of a task-based approach to design is increased by recent changes in policy to develop contracts based on 'performance criteria' rather than 'detailed design criteria'. In this approach a compartment layout must be evaluated against criteria such as "allow crew to perform tasks 'n, m'" or "the layout must be optimized for the performance of existing naval communication protocols".

Currently, design personnel responsible for reviewing the human factors aspects of ship spaces obtain information on operator tasks from other personnel in the design office who have operational experience. As design teams continue to downsize and turnover remains high the source of task information draws from a smaller number of experiences. The availability of operational information decreases and the quality of the input becomes less reliable.

HFEICADD was developed to provide a tool to be used by all personnel responsible for the review of HFE issues in the design of naval vessels. In this role it is expected that it will be used by both 'sides' of the procurement team: the government authority and the contracted design staff.

The tool itself focuses on the HFE issues associated with compartment layout. Examples of these issues include workstation design, the positioning of controls and displays, the layout of bridge and communication spaces, passage widths, deckhead heights, and emergency routes.

HFEICADD must be compatible with a family of existing products supported by DCIEM and the Directorate of Ship Engineering, including: NEWTONES - a database of ship personnel and the functions (and tasks) they perform in the various compartments; ERASMUS - a tool to decompose ship functions to determine personnel required; MANIAC - a tool to determine the shipboard habitability requirements depending on the numbers and types of required; VAPS - an interface development tool used to produce detailed rapid prototypes of instrumentation and controls; SOLE - a relational database system for decomposition of functions and operator tasks, and, HFE-GUIDE - a hypertext integration of human factors design criteria.

2. User Centred Design Process

The development of the HFEICADD system has been a user centred, iterative, design process. This began with an analysis of the ship design process in Canada and the various design and design-review tasks, followed by focus groups with naval architects and both navy and industry human factors personnel [5]. The design of HFEICADD has undergone several reviews with the future user community including usability trials where potential system users completed representative design review tasks over several days. The results of each user review have been integrated into the next cycle of development.

3. Modular Design

The HFEICADD system is comprised of an integrated set of custom developed and off the shelf software products [6, 7]. The various software packages are incorporated into five modules (Figure 1).

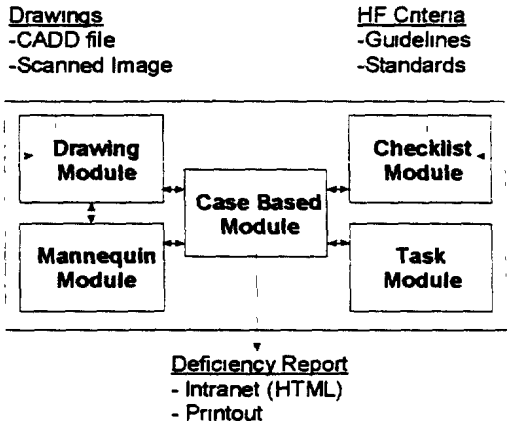

Figure 1: HFEICADD SYSTEM

The Checklist Module incorporates the knowledge of experienced designers and reviewers in the form of design checklists and guidelines. This tool provides a database of HFE design criteria that can be extracted as necessary to develop checklists for the review of specific compartments. The creation, completion, and archiving of these checklists occurs in the this module.

The Drawing Module provides the user with a CADD tool capable of importing the latest layout of a compartment and Redlining tools with which the reviewer can highlight areas of concern and make comments on the layout. These Redline images and text are also available for integration into a deficiency report. The drawing tools are currently comprised of Microstation as the CADD tool and CadLeaf as the Redlining tool.

The Task Module incorporates information on who works in a compartment, what tasks they have to perform and the key visual, travel, and communication links associated with task execution. Within the HFEICADD system these data can be transferred between reviewers to allow the knowledge of task behaviour to grow as different users interact with a compartment under design. This helps to

ensure that all reviewers and designers are making decisions within the same framework or context of ship crew performance. In addition to the task data associated with each compartment, the design team can include a video clip of the configuration of the space. This video feature is useful later in the life cycle of a ship when design changes are being evaluated and allows the user to compare drawings to the actual space. The Task Module is a custom application built by the project team.

To enable the reviewer to conduct more complex HFE trade off studies a powerful human form modelling capability is provided by the Mannequin Module. This tool allows the user to import 3D renderings of a ship space or to quickly create their own drawing of key features of a space. Representative human form mannequins are then inserted into the 3D environment where lines of sight, reach, force requirements, travel clearances and other variables can be evaluated. These 3D visualizations, with mannequins inserted, are also available for illustrating design concerns in the design review report (the deficiency report). The mannequin tool chosen for HFEICADD is SAFEWORK by Genicom [8].

Within the Case Based Reasoning Module, the custom designed Deficiency Report Generator provides a template that allows the user to integrate a variety of inputs from the design review into one comprehensive report. Deficiency Report information can include: completed checklists and related commentary; passed or failed checklist items; graphic files with Redlines and comments, and; 3D views with mannequins. These reports are the core product used for tracking design decisions related to human factors issues. The report generator takes the selected contents of the deficiency report and generates an HTML file. This allows these reports to be distributed over an Intranet environment, with the review team using their World Wide Web browsers to review and track design compliance.

The 'intelligent' aspects of HFEICADD are resident in the Case Based Reasoning Module [9]. In its simplest form this tool allows a reviewer to search the system for design reviews where similar design issues have been evaluated. This allows the less experienced designer to view examples of how criteria have been interpreted in other cases and encourages all users to maintain consistency in their evaluations. The module incorporates a Thesaurus Tool that allows them to develop a thesaurus of terms related to human factors issues in ship design. With the Thesaurus Tool users can expand any search to related or 'like' design issues that have been experienced in other reviews. This engine and its 'near neighbour' algorithms should increase the number of search 'hits' provided the Thesaurus is developed accurately.

Another aspect of the Case Based Module that should be useful to novice users is the ability to understand HOW a compartment review was conducted. In addition to search options associated with context, design problems and design solutions, the user can also search on review methods. The results of this search identify which of the many HFEICADD tools were used to conduct a previous review and allows the user to access those files to check on the extent of the analysis conducted.

One of the more experimental aspects of the Case Based Module is the Automatic Constraint Checker. This tool contains a library of graphical objects along with a set of design criteria [10]. This feature will allow HFEICADD users to identify a *.DXF file and ask the system to automatically check it for deficiencies. The Constraint Checker will then interrogate the file for known graphical objects (walls, doors, desks, chairs, etc...) and identify any known conflicts (passage widths, clearances, etc..). This tool is required as the users of HFEICADD may not be working within a controlled CADD design environment and must be able to import a range of design files and analyze them without the assistance of a defined object library.

All of the interfaces for the Case Based Tool, including the Thesaurus, the Case Searching Tool, and the Constraint Checker are custom HFEICADD applications built in HTML and JAVA to allow the users of HFEICADD to interface with their Web browsers. These tools have been made Web based as other project users may have a need to review the HFEICADD information from a variety of different hardware platforms.

4. Using the HFEICADD System

The users of the HFEICADD system will be able to perform the following types of tasks to review and document human factors issues with a design [5]:

- Develop a Review Project
  In order to allow HFEICADD to track HFE issues by compartment type, the user must define each compartment or specified review effort as a project. This allows specific checklists to be designed for specific compartment types and deficiency reports to be linked to areas of interest. The user will select an existing project, or define a new project, using a simple graphical interface. The user can access the five HFEICADD modules from the System Administrator menu.
- Review History or Related Studies
  Because of the multiple layers of review in the collaborative process, most users review only the

results of reviews by other professionals and confirm or alter preciously established conclusions to develop their own deficiency reports. As a result, most users will open a new project for review, access the previously developed checklist, and then start their review from the issues marked non-compliant by a previous reviewer. An inexperienced user may want to start the review process by reviewing how similar human factors issues have been handled in other compartments on the same or on other ships. She can select the Case Based Module to: review the history of a design review for a specific compartment; identify the HFEICADD facilities that have been used, or; to review the approach taken to HFE reviews for similar compartments. The search engine will provide the user with access to previously completed checklists, Redlined drawings, and deficiency reports so that users can trace the history of a similar design issue through a similar case.

- Prepare a Drawing for Review
  The user must load a file with the drawing to be reviewed, either by accessing it from the DND or contractor's project network, or scanning it on a flatbed scanner if it is available only on paper.
- Determine Items to Check on Drawing
  The user selects and reviews available checklists and selects one, or develops one, for the compartment in question and for issues that can be reviewed at the particular stage of design. The user develops custom checklists based on the master human factors criteria for the ship and links this checklist to the compartment review project.
- Check Items on Drawing According to Non-Compliant Items Identified by Contractor
  The user reviews the compartment drawing using the developed checklist(s). He could invoke the Automatic Constraint Checker, depending on the extent of novelty in the compartment design.
- Check Items on Drawing According to the Tasks Performed in the Compartment
  To better understand the tasks to be performed by the crew in a compartment under review, the HFEICADD user can select the Task Module. This will provide access to information on who works in the compartment, what task they perform, and what movement or information links are required for task performance.
- Conduct Complex Human Factors Analysis
  In some cases the decisions to accept or reject a design will require more complex analyses. The user can select the Mannequin Module to develop a 3D representation of the space and analyze task demands using human form mannequins. An example might be to create a layout of a communications space and evaluate the reach envelopes to different interfaces, or to evaluate which displays are visible in the users' primary visual zones.
- Record and Review Decisions and Rationale
  Once the user has completed all reviews she can generate a deficiency report by selecting the deficiency Report Generator. The user can incorporate into the report different categories of checklist items (pass, fail, can't say) as well as any graphics used in the review (CADD, Redliner, Mannequin).

5. Future Activity: Virtual Reality

The HFEICADD system is nearing the end of its four year development cycle, with final usability trials to be held in mid 1997. Concurrently, feasibility studies are being completed to investigate the integration of both local and distributed virtual reality technology. The integration of this technology into the HFEICADD system will allow the layout reviewer to experience the design from the perspective of a user with different sensory or physical characteristics, and allow them to more directly experience task completion within the context of a future design.

6. Conclusions to Date

Usability trials of the HFEICADD system conducted to date suggest a high utility for the product within collaborative design teams [11]. Features which users have found attractive include the checklist system and the task database. Both of these tools ensure that the context of a design review, as well as the criteria and rationale associated with design decisions, are available to all users across the geographical and temporal distribution typical of a ship design team.

Positive feedback has also been provided regarding the potential use of HFEICADD in design environments other than ships, and for issues other than human factors. The potential for transfer to other domain areas is enhanced by the HFEICADD architecture, which allows interchangeability of the products used in each of the modules as long as compatible file formats are retained.

7. References

[1] BEEVIS, D. 1987. Experience in the Integration of Human Engineering Effort with Avionics System Development. In: Proceedings of the Conference on the Design, Development and Testing of Complex Avionics Systems, AGARD-CP-417. Neuilly-sur-Seine, France: AGARD. pp. 27-1 to 27-9.

[2] HUMAN*SYSTEMS* INCORPORATED 1992 Integration of Human Engineering Data with CADD Software for Shipboard Workspace Design. *Contract Report to DCIEM.* North York, Ontario: Defence and Civil Institute of Environmental Medicine.

[3] HUMANSYSTEMS, PROTOGON, AND GENICOM 1994. Proposal to Provide a Computer Based Human Factors Engineering Tool for Ship Design. *Proposal to Supply and Services Canada.*

[4] MORGAN, C.T., COOK, J.E., CHAPANIS, A. and LUND, M.W., 1963. Human Engineering Guide to Equipment Design: Chapter 8 - Arrangement of Groups of Men and Machines. New York: McGraw-Hill.

[5] HUMAN*SYSTEMS* INCORPORATED. 1995. ICADD System for the Ship Design Review Process: Human Factors Task Analysis. *Contract Report to DCIEM.* North York, Ontario: Defence and Civil Institute of Environmental Medicine.

[6] PROTOGON, GENICOM and HUMAN*SYSTEMS.* 1995. ICADD System for the Ship Design Review Process, Part 2: System Architecture Tools Selection. *Contract Report to DCIEM.* North York, Ontario: Defence and Civil Institute of Environmental Medicine.

[7] PROTOGON, GENICOM and HUMAN*SYSTEMS* 1995. ICADD System for the Ship Design Review Process, Part 3a: Detailed System Design. *Contract Report to DCIEM.* North York, Ontario: Defence and Civil Institute of Environmental Medicine.

[8] SAFEWORK: 3D Human Modeler for Workspace Design and Ergonomic Analysis. See <www.safework.com>

[9] PROTOGON SYSTEMS INC. 1995. ICADD System for the Ship Design Review Process, Design Notes: The Case Storage and Retrieval Mechanism. *Contract Report to DCIEM.* North York, Ontario: Defence and Civil Institute of Environmental Medicine.

[10] PROTOGON SYSTEMS INC. 1995. ICADD System for the Ship Design Review Process, Design Notes: The Automatic Constraint Checker. *Contract Report to DCIEM.* North York, Ontario: Defence and Civil Institute of Environmental Medicine.

[11] HUMAN*SYSTEMS* INC. 1996. ICADD Usability Trial 1: Final Report. *Contract Report to DCIEM.* North York, Ontario: Defence and Civil Institute of Environmental Medicine..

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