http://dx.doi.org/10.5516/NET.04.2013.701

A QUALITATIVE METHOD TO ESTIMATE HSI DISPLAY COMPLEXITY

JACQUES HUGO* and DAVID GERTMAN
Idaho National Laboratory, Human Factors Department
2525 Fremont Avenue, Idaho Falls, ID 83415-3605
*Corresponding author. E-mail : jacques.hugo@inl.gov

Received December 27, 2012

There is mounting evidence that complex computer system displays in control rooms contribute to cognitive complexity and, thus, to the probability of human error. Research shows that reaction time increases and response accuracy decreases as the number of elements in the display screen increase. However, in terms of supporting the control room operator, approaches focusing on addressing display complexity solely in terms of information density and its location and patterning, will fall short of delivering a properly designed interface. This paper argues that information complexity and semantic complexity are mandatory components when considering display complexity and that the addition of these concepts assists in understanding and resolving differences between designers and the preferences and performance of operators. This paper concludes that a number of simplified methods, when combined, can be used to estimate the impact that a particular display may have on the operator's ability to perform a function accurately and effectively. We present a mixed qualitative and quantitative approach and a method for complexity estimation.

KEYWORDS : Information Complexity, Information Density, Semantic Complexity, Human Factors

1. INTRODUCTION

Research in perception and human reliability has shown that reaction time increases and response accuracy decreases as the number of elements in the display screen increases (Tufte 2001; Ngo and Byrne 2001, Xing 2004). A report by Cummings et al. (2010) has identified display complexity as one of the key contributors to human error. Research cited in that report also shows that the complexity of a display as a whole will be a function of the complexity of discrete patterns or objects, and the complexity resulting from the variable orientations and locations of these patterns or objects. Human errors made while viewing displayed information can result from errors in navigation, execution, interpretation, and the selection and use of immediately available information. Previous guidance suggests that potential reasons for human error include inaccuracies in the information presented, illogically organized data, mispositioned labels and other descriptors, and inconsistent messages to users. (Banks and Weimer 1992; Gilmore, Gertman, and Blackman 1989). In the past, hardware issues such as phosphor persistence and screen flicker were also believed to influence display navigation and to interfere with aspects of comprehension and interpretation. From a human factors approach, improved display design including control of the display density was considered an easy fix for this problem.

Over the past 20 years, a multitude of advances in hardware and software technologies have given designers much broader and more effective flexibility in screen design and the crafting of human-system dialogue. Along with these advances has come the realization that the increased ability to present information to operators has its own problems. One suggestion for improving performance is to reduce the sheer volume of information present on the screen, but an almost stronger tendency is to increase the information available, often at the suggestion of the end user. This being the case, we should ask, what is missing in the definition and assessment of *display complexity* (DC) that allows this to happen?

Human factors specialties, such as human reliability analysis (HRA), are beginning to recognize the importance of screen design and human system interaction in automated environments as contributing elements in response to operational disturbances and are attempting to refine the current generation of methods (Gertman 2012). Recent research (Xing 2004) sponsored by the aviation industry reviewed the complexity factors of variety, quantity, and relations and sought to map them to perception, cognition, and action (Gertman 2012). However, before HRA can be improved, the phenomena and effects of complexity in screen displays on operators' understanding of plant status and related errors must be understood. This paper addresses the important aspect of assessing and understanding complexity in screen design.

Additional approaches regarding complexity include research at a systems level in terms of emergent systems properties and performance, the degree of uncertainty, and the extent of subjectively experienced difficulty. Complexity concepts considering these kinds of factors are presented by Walker et al. (2009).

The complexity of the human-system interface involves more than just screen display density. The approach used in this paper examines display screen density, DC, in relation to contextual importance and semantics, and relations among various elements of screen design. This is done by examining a number of concepts illustrated with example cases of contemporary displays. This approach presents a qualitative means for conducting evaluations that can be used in the design of displays, or if more empirical limits are desired, to help in the design of studies to determine boundary conditions. This approach can also be used when determining the appropriate levels assigned to performance shaping factors when conducting HRA.

2. ESTIMATING SCREEN DISPLAY DENSITY

The density of an existing display can be estimated by dividing the screen area into a grid. Each grid element is assigned a density value based on the number of objects (or parts of an object) contained within it. The distance from each object within the grid to the centre of the grid element is subtracted from the diagonal length of the grid element and added to the density tally for that grid element (adapted from Faichney 2004) as expressed by

$$D(x,y) = \sum_{i=1}^{N} l - |OiG| \tag{1}$$

where:

- D is the density at coordinates (x,y)
- N is the number of objects within the grid element
- l is the length of the grid element's diagonal
- $|OiG|$ is the distance from the centre of object Oi to the centre of grid element G.

The maximum density would be l^2, that is, when the entire grid element is taken up by one object.

Visual Density as a percentage of maximum potential density per grid element is thus expressed by:

$$D\% = \frac{D}{l^2} \times 100. \tag{2}$$

In the first example, a single grid element captured from an HSI screen is shown in Fig. 1.

The five significant grid elements in Fig. 1 are identified in Fig 2.

The calculation of the OiG value of the five grid elements (numbered clockwise) are:

O_1G : 30 - 11.34 = 18.66
O_2G : 30 - 4.05 = 29.95
O_3G : 30 - 6.7 = 23.3
O_4G : 30 - 7.45 = 22.55
O_5G : 30 - 4.84 = 25.16

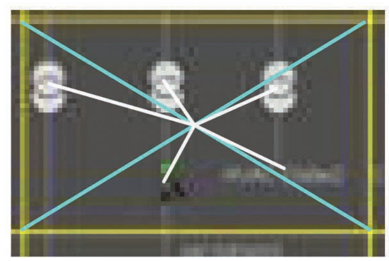
Thus:

D = 119.62, D% = 13.3

A second grid element captured from an HSI screen is shown in Fig. 3.

The 21 significant grid elements in Fig. 3 are identified in Fig. 4.

Fig. 1. Grid Element Captured from and HSI Screen.



Size of grid element = 25.7 × 15.6 mm
Number of objects within element (N) = 5
Length of grid element's diagonal (l) = 30 mm
Maximum potential density (l^2) = 900

Fig. 2. Significant Grid Elements in Fig.1

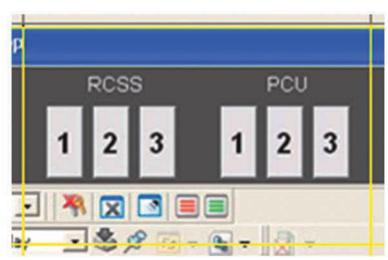
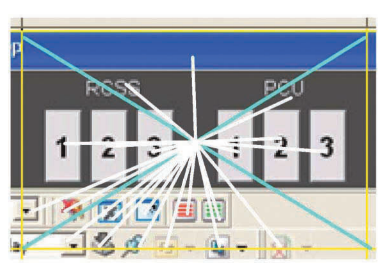


Fig. 3. Second Grid Element Captured from an HSI.



Size of grid element = 25.7 × 15.6 mm
Number of objects within element (N) = 21
Length of grid element's diagonal (l) = 30 mm

Fig. 4. Significant Grid Elements in Fig. 3