THE USE OF AN INTERACTIVE DISPLAY UNIT TO SIMULATE THE DATA MANIPULATION AND DISPLAY NEEDS OF AN AIR TRAFFIC CONTROL SECTOR

Professor M.L. Constant, Professor T.L. Seeley
and
J.K. Cook, G.J. Savage, J.G. Wilson
University of Waterloo

The work done on this application of an interactive graphic display unit formed part of a MOT contract let to the Industrial Research Institute of the University of Waterloo. Very broadly and simply, the contract's overall objective was to examine the present use of flight data in air traffic control and recommend a suitable display concept for further development.

As part of this work, a simulation was designed in order to be able to evaluate the visual impact of data formats and layout, as displayed, and also to simulate the ergonomics involved in the proposed interactive device, which was not available. Acknowledgement is made to Mr. FND Gilbert, Superintendant, Computer Systems, Communications and Electronics Branch, Ministry of Transport, for permission to present the simulation work in this paper as an example of work in the computer graphics field.

The principal investigators were Professors Maurice Constant and Les Seeley of the Dept of System Design, Faculty of Engineering. The basic system design of the simulation, plus all program design, writing and development, was completed by the two research assistants, Mr. J. Ken Cook, MASc, and Mr. Gordon J. Savage, MASc. Consultant operational assistance was provided by Mr. John G. Wilson, MCASI, ARAeS, a former air traffic controller.

The need for such a simulation arose when it became clear that a preferred interactive device would not be available for actual evaluation. This is a Marconi (UK) device* known as "Touchwire", and presently used in the UK ATC system. It consists of a plastic overlay for a CRT, having pairs of wires embedded in it. A short length of each pair lies bare above the surface of the plastic giving a total effect of a matrix of touch-contact wires. Five-bit logic enables an 8x4 matrix to be used in a way that permits any wire that has been touched to be identified by software. With such an overlay in place, it then becomes a programming exercise to generate a "menu" of text items for display under each touchwire. Selecting any menu item by touching a wire "turns the page" and displays the next hierarchy of choices, until at the final level data is entered for processing. This is the device which was <u>not</u> available and which had to be simulated.

* Plessey Co. Ltd. also make a touch wire device.

The timescale was short and it was necessary to use available hardware. This consisted of the DEC PDP9 computer with 24K core capacity; the 340C graphic display and its associated control box; and the RB09 disc. It was decided to generate a two-row menu of five items each, to correspond visually with the layout of the ten buttons of the control box and to locate the control box physically close to the CRT in order to permit easy visual correlation of menu item with button. The pressing of a button would then correspond to the touching of a wire. Because of previous work which had been done by Ken Cook and Gordon Savage using the PDP9/340C combination, software already existed to generate menus and text. Although this was an undeniable advantage, the majority of the programming still had to be done.

The basic data being used consisted of discrete blocks of separate data items, corresponding to the data items in an aircraft's flight plan. Each block had to be entered into the processing system (in the simulation, read from cards), and stored in a data base for subsequent retrieval and display. In addition to being stored, calculations had to be performed upon some of the data items and these results also stored for display. Typically additional times had to be calculated from the initial times and speed data. Selected data items then had to be organized into a specific format and displayed as text in a specific layout.

From the same data base one data item, the aircraft identity, was also required for display in the fundamental menu. Initial selection of this item caused the complete block of data associated with the selected aircraft identity to be displayed additionally in a special format and location. At the same time, the basic display of selected data items from all aircraft was maintained, and the menu changed to the next hierarchy. This consisted of descriptions (such as speed, altitude, etc) of data items which could be interactively modified for the aircraft which had previously been selected, and whose full data was now displaying.

This process proved to be more than just a matter of data substitution since some data items, themselves, interacted with other data. A change of speed, for example, required times to be recalculated. Changes of altitude affected other displayed altitudes. And in addition a search was being conducted, after each data manipulation, to compare some specific data items for all aircraft against each other, and also against a criteria that was looking for pairs, a process known as conflict search. And while all this was going on, the display still had to be maintained.

Compounding this complexity was the fact that the whole display had to simulate real time, since some of the data items, and also the display criteria and formats, were system-time dependant. So a displayed real-time digital clock became part of the system. In addition to all this, an alternative display feature was incorporated as a menu selected option. This served the purpose of deleting all displayed text items and generating, instead, a picture of the simulated route network system. On this picture of interconnecting lines, symbols were placed in the calculated scale position of each aircraft in the system. Associated with each symbol was a text label of the appropriate aircraft identity and altitude. This pictorial display was recalculated each time it was selected, so that it always showed the latest updated situation. Button interaction against a single word menu permitted a return to the all-text display.

The total software package was designed and produced in six weeks from scratch to the first successful display of data in a suitable form. A further four weeks development work was needed to refine the logic to the point where the displayed data behaved in an authentically operational manner. At this point it became an excellent evaluation tool for the purpose of assessing the ergonomics of the interactive element, and also the visual impact of formats, layouts, character sizes and intensities.

Some effects and requirements which became apparent only after seeing the data displayed on the CRT were:

1 Data should be ordered in justified columns. It then becomes very easy to scan ETAs or altitudes when making control decisions.

2 Strips should not be indented as an attention cue. It is confusing to see a break in the columns of data, particularly if two or more consecutive strips are indented. A special attention symbol serves as a more useful cue.

3 A difference in character size creates a most useful emphasis. In ATC the convention is to print the aircraft identity at the leading end of the sequence of data items referred to as a strip. This signifies the direction of flight. In columnar form this looses some of its impact. If the character size is made smaller, the strip takes on a sense of direction, but there is a considerable loss of readibility of this field. However by reducing the size of the trailing end field (see figures 1-4), the sense of direction is preserved without affecting the quick visual registration of aircraft identity. One hardware limitation was the coarse range of character sizes. A finer range would probably have achieved the same objective without loss of readibility.

4 Data packing within the limitations of the available display area was successfully achieved by single spacing strips whose ETA (a time calculated in the data processing) was more than twenty minutes from system time. At this time parameter, the single spacing became double spacing to permit the display of additional information.

5 A cueing symbol should be displayed with each item of new data until it is acknowledged. It was found that new data appears very unobtrusively and an attention cue appeared to be desirable.

6 Underlining can be an effective visual cue, as can be seen from the figures. Experience of other systems indicates that different character sets (eg: italicised), or inverted polarity can also be very effective.

7 "Crossing out" data on the CRT is necessary where the fact that the data has been deleted is, in itself, an item of information. Overwriting dashes or slashes through each character can accomplish this very effectively.

8 Conflict attention cues are best displayed in the altitude columns. The controller usually must make an altitude decision, and these cues so placed draw his eye to the relevant data. It is easy to scan the aircraft identities once the eye has settled on the conflicting altitudes.

8 Many ideas in menu-ing for the data display came out of the simulation, and, in fact, the menu handling routines have been re-designed in the light of these lessons learnt. Some of the points are;

(a) The "readback" line is extremely important. Without it distractions can cause input errors.

(b) Format checking should be done during entry so that only the selection of the right number of digits satisfying the parameters causes the "enter" menu to be displayed. This provides a very "goof-proof" and acceptable procedure, which prevents incorrect entries tying up the software with diagnostics.

(c) The order in which menu items appeared could be important since the optimum order for each sector may be different. This dictated that the menu displays had to be versatile enough to allow for reconfiguration of the hierarchy with minor reprogramming effort.

Figure 1 shows aircraft data organized in its normal columnar presentation under two beacon headings. An operationally authentic quantity of detail has been synthezed and the traffic situation represents a quite busy ATC sector.

Figure 2 shows a pictorial display of the situation represented by the aircraft data in figure 1. Today's controller is used to seeing data organized in the manner of Figure 1. This simulation enabled an evaluation of an alternative method to be obtained.

Figure 3 shows the conflict analysis readout obtained by selecting any aircraft showing an attention cue.

Figure 4 shows the readback line containing a complete and valid entry just prior to execution.

Figure 5 is a flow diagram of the main supervisory or executive program.

The button interrupt, internal clock, time-activation, and menu handling routines were all written in assembly language. The remaining programs were all written in FORTRAN, the assembly language programs having been designed to be called by the

FORTRAN supervisory program. Total core usage was of the order of 16K, although a 24K configuration is required to run the simulation effectively. Retrospective redesign in the light of the experience gained would probably reduce the size to about 12K. The whole exercise proved to be an object lesson in what can be achieved on such a display using a high level language and an inefficient compiler, when core usage is not at a premium, and the time factor is important. Without language programming and the on-line editor, the time-scale would have been multiplied by a factor of three at least. The conclusion reached was that a valuable evaluation tool had been created for both the interactive element, and also the processing and display format elements. This had been achieved within the capabilities of available hardware, and a great deal had been learned about the design philosophy of such ATC data processing and display systems, which are invariably complex. This experience will be put to good advantage in any further work in this area.

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Figure 1

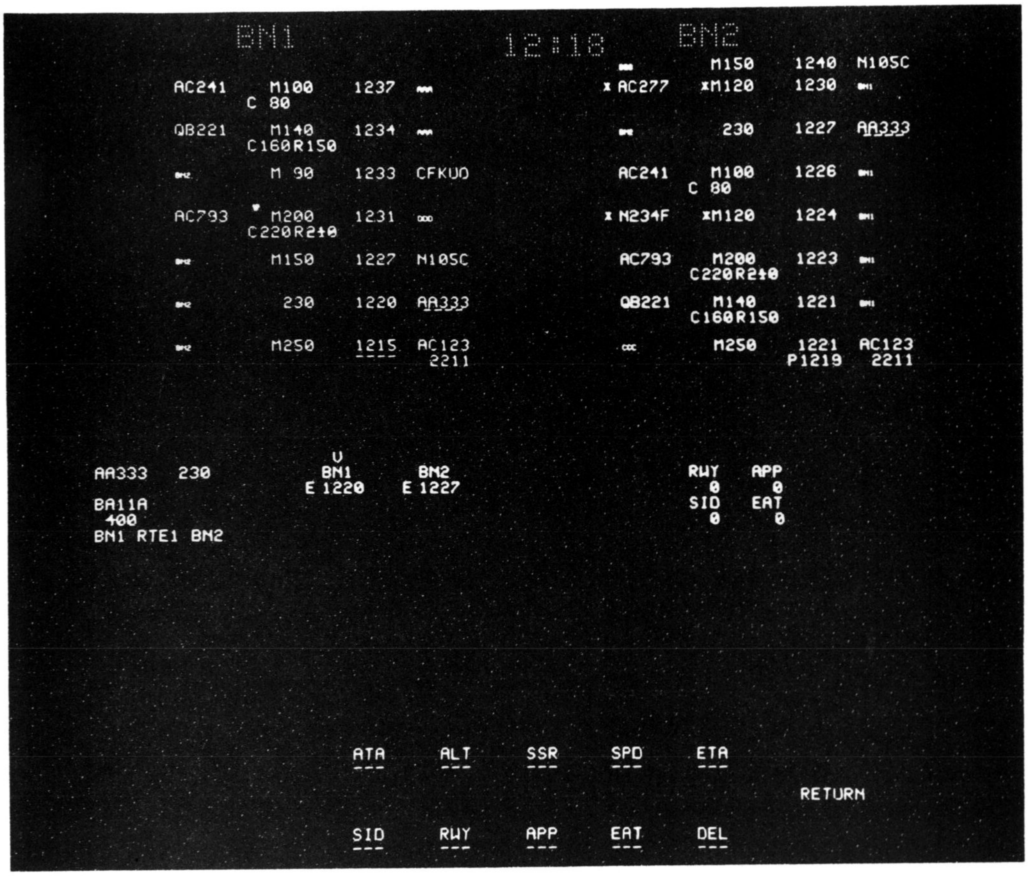

Figure 2

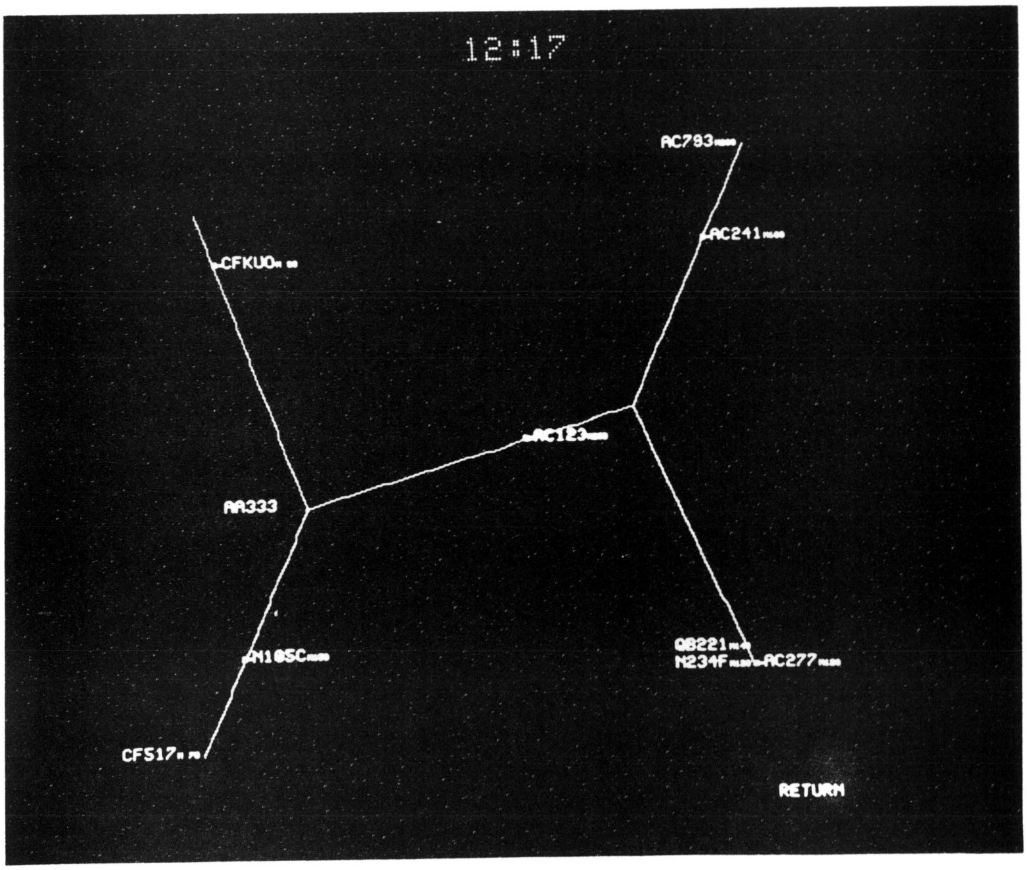

Figure 3

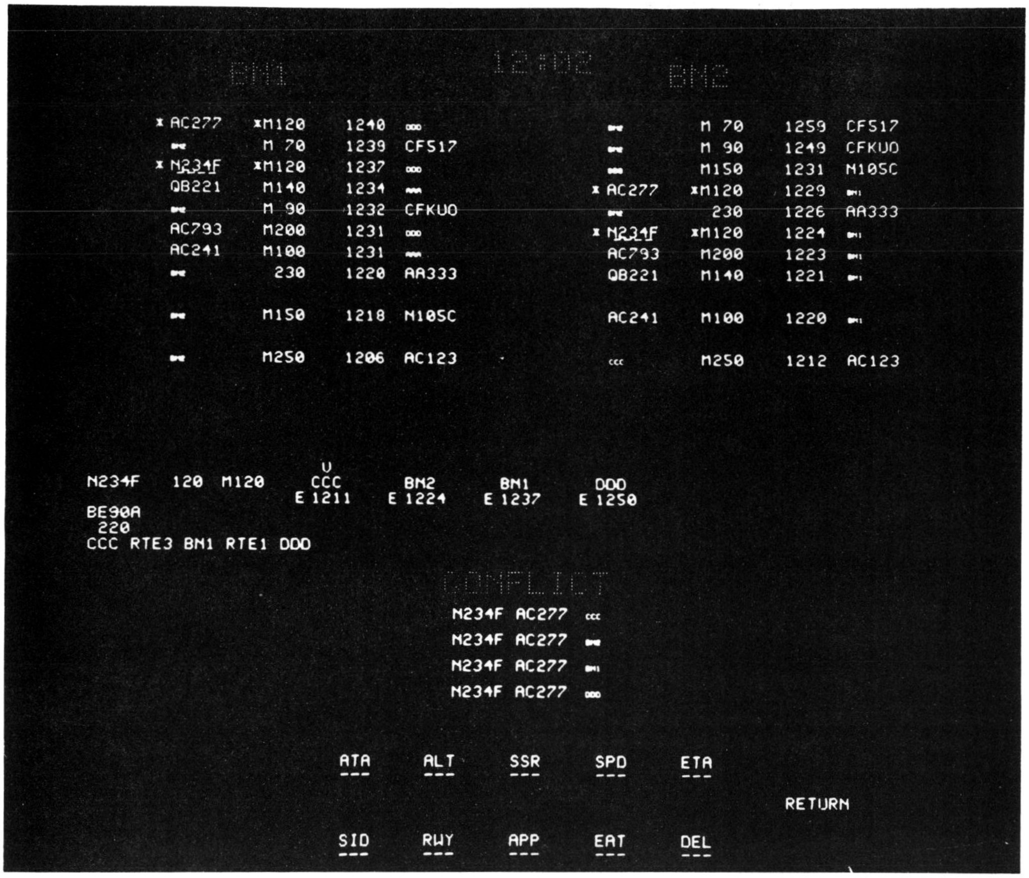

Figure 4

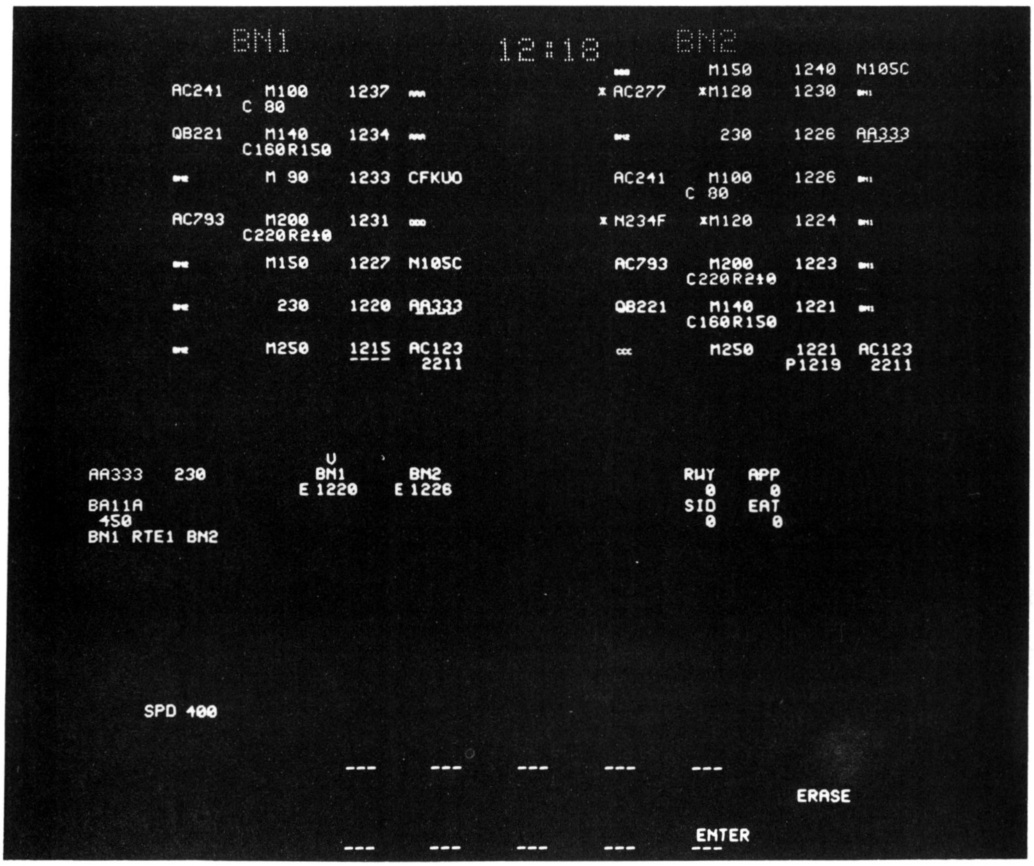

Figure 5

EXECUTIVE PROGRAM